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What Is New in Power Transmission?

PROBABLY the earliest recognized device for the transmission of power was the lever of Archimedes. For many centuries, simple applications of the lever, the screw, and the inclined plane constituted the sum and substance of all power transmission equipment. The muscles of slaves, oxen and horses, and later the crude use of water power, called for no great ingenuity in the development of transmission mechanisms.

When the harnessing of steam revolutionized industrial production methods, the picture changed. With power available in large amounts, and with its uses and applications continually increasing, transmission methods and devices became important. The development of electrical power gave added impetus, both by its own requirements and by reason of its competitive stimulation to the field of mechanical transmission.

If we were to plot a curve to show, by years, the progressive development of the art—now become almost an exact science—of power transmission, the line would run almost horizontally from the time of Archimedes to the period when steam power was introduced. From that point, the curve would start upward, with steadily increasing steepness, until today it approaches the vertical.

It is one thing, to name the earliest recognized device for the transmission of power; it would be quite another thing, to attempt to name the latest and most efficient device. To use a figure of speech which would not be very far from the literal truth, we might say that the most efficient power transmission device was perfected yesterday, will be serving industry tomorrow, and may be superseded by something even better before next week.

This does not mean that equipment installed today will be obsolete six months from now. It means, simply, that in the last few years the manufacturers of power transmission equipment have put research and engineering ingenuity to bear on the problems in their field. Not only that, but they have undertaken to educate the industrial engineer in the advantages of modern, efficient transmission.

Since the post-war deflation, cost-cutting has been the paramount concern of every industry. Power generation costs have been brought down, production machinery has been improved and speeded up; and the important link between these two—power transmission—has begun to receive the attention it merits.

What has been the outstanding development in the field of power transmission during the past few years?

"I have been in this business for twenty-eight years," says Charles E. Brinley, President of The American Pulley Company, "and have seen more live interest in the subject of correct and economical power transmission during the last two or three years than in the first twenty-five." Going on to a discussion of the effect of larger factory units, with their more complex problems and greater engineering facilities, he continues:

"Of course every one knows that power drives are roughly divided into two clasifications, i. e. the mechanical drive and the direct electrical drive. The mechanical drive was first in the field and almost universally used for many years. Electrical motors, however, appeared and demanded and obtained a large degree of recognition. Indeed, to some extent, it became the fashion to use direct drives more or less regardless of circumstances. I should say that perhaps the most conspicuous thing in the transmission field today was the definite acceptance by engineers of the fact that to provide the best working conditions in a factory, it is nec-

essary to combine both types of drives based upon the actual merit of each as it appears for the purpose at hand."

Howard Dingle, President of The Cleveland Worm & Gear Company, observes:

"During the past few years industrial engineers and executives have become more and more conscious of the economies that result from modern transmission practice. Formerly any available gear, belt, rope, chain, or what-not, might be used to solve a power transmission problem; but now ultimate economy through dependability, durability and efficiency is the goal in every selection of power transmission equipment. Life of transmission apparatus without replacements or repairs is now measured in years instead of months."

ON THIS same question of the outstanding developments in the field of power transmission during the past few years, it is interesting to turn from the opinions of manufacturers, to those of the industrial engineers in a variety of industries. R. D. Moore, Chief Engineer of DuPont Rayon Company, Buffalo, says:

"I have been very favorably impressed with the progress and possibilities in all-electric variable speed transmissions; in the short-span drive known as Texrope; and in the tendency toward simple roller chain transmissions with a higher speed ratio than formerly. There have also been introduced, I believe, a greater variety of reliable speed reduction units of various gear types, including better variable speed reducing gears which are of interest to quite a few industries including our own."

Turning to the electrical phase of power transmission, A. E. Windle, Plant Engineer of Wilbur-Suchard Chocolate Company, has this to say:

"It is our belief that the use of synchronous motors and other motors of horsepower output close to the requirements of the loads to be driven, with a view in each case of securing a better power factor, has been one of the most closely studied problems of power transmission and use in recent years.

"In the individual plant the standardization of equipment within the plant itself, that is, as to makes and varieties of the different pieces of equipment, combined with the scheduling of maintenance work, including the overhauling, inspection, lubrication and replacement of various pieces of equipment, has had a great bearing on increasing the economies possible in connection with plant operation in general."

From H. D. Fisher, Plant Engineer of The New Haven Pulp and Board Company, comes the following comment on power transmission developments in the paper industry:

"I believe that the most striking development of the past two years has been the very general use of inclosed speed reducers and also of short center drives such as the Lenix and Pulmax, and the V-belts such as Texrope and Cog Belt. In the paper industry, group drives of large units have been usual, and the change in transmission has caused comparatively little saving in power cost alone, but has resulted in better service from proper design of drives, with reduced maintenance, at comparatively little greater first cost. The chief benefits have been the ability to supply the considerably larger amounts of power required by improvements in process work, and also great reduction in space occupied; the latter often sufficient to postpone considerably the erection of new buildings."

Elmer Housley, Electrical Engineer with the Aluminum Company of America and Superintendent of the Talassee Power Company, Western Division, and of the Knoxville Power Company, says:

"It seems that the changes which have been made in this equipment in the past few years have exceeded the progress made in the previous twenty years. Several years ago, we had a certain horror of worm gear reductions or straight-line spur gear reduction, and I believe we were justified. The first worm gear drives were a crude device and they have been improved rapidly, so that within the past two or three years no well-informed engineer would hesitate to install one. The same process of development has been experienced by the spur gear reducers, and today they, too, stand as a standard device.

"Maintenance has been simplified by improved oiling systems. No longer is it necessary to screw down a grease cup every few hours. Lubrication is now sealed in, and dust sealed out, and the figures on the Repairs and Maintenance sheet grow smaller.

"Quite often, a careful study will indicate that it is economy to consign much of the existing transmission equipment to the junk pile. Too many plants are prone to lose money, and not know it, because everything is working fine, and why bother it? Such smug complacency is encountered often, and the engineering department is failing to function as it should unless it keeps in close touch with new equipment developments."

K. D. HAMILTON, Plant Engineer of George E. Keith Company, manufacturers of Walkover Shoes, mentions modern speed reducers and the use of anti-friction bearings as two of the outstanding developments of recent years. "Engineers today are studying the relationship between investment costs and power savings," he continues, "in order to determine the most economical equipment to install. There is a tendency in all industries to standardize as much as possible on transmission

equipment in any particular plant. This standardization policy has eliminated the necessity of carrying extensive inventories and reduces the number of parts in stock. Much more particular attention has been paid to the installation of belting, in the last few years. Belting has been standardized, in many respects, and in progressive plants all machines are classified and the proper belt specified for each installation. It costs just as much to put on a good belt as a poor one; the difference is, that the poor one will require twice as much attention and repairs after it has been put in operation.

"This phase of belting maintenance is an important one because of the breakdowns to production machinery which result from the application of an inferior article. It is not always the cost of the belting which should be taken into consideration. It is the expense of shutting down a production machine while waiting for repairs and the labor for these repairs, as well as accessories, such as belt hooks, belt dressing, lacing and other material which go into the belting maintenance."

FROM the limestone quarries comes, once more, observation on the electrical phases of modern transmission practice; this, from J. F. French, Electrical Engineer of the Indiana Limstone Company:

"In the Indiana limestone quarries of southern Indiana, the one outstanding betterment in transmission which has been made, is that in electrical power transmission.

"Up until about two years ago, the proper distribution of electrical energy, particularly around the various quarries, was something which had been given very little attention or thought. Consequently, voltage conditions were extremely bad, energy losses were high, and maintenance costs on electrical equipment were prohibitive. This all meant considerable loss in time of various machine operating hours, waiting on electrical repairs.

"No definite scheme of distribution had been evolved. Wire sizes were invariably small for the load imposed upon them, and weather-proof and rubber covered wires were used. These wires were strung out over rock piles and on the ground, and left there, and before long, insulation would be off and numerous grounds occurred with consequent troubles.

"This has all been changed. A definite distribution scheme has been worked out. Transformer banks are located adjacent to load centers. Wire sizes carefully checked, and put in of ample capacity to handle load. On top of quarry ledge, secondary wires are mounted on vertical racks, put on lines of stub poles. All distribution from top of ledge to cutting machines down in quarry holes, is made by means of large size portable drag cables of standard manufacture. All troubles as previously contended with, due to grounds and low voltage, have been eliminated.

"In the cut stone plants, many improvements have similarly been worked out, though not so pronounced. There, we have also gone to either ball or roller bearings on our major group line shaft drives. Every effort is being made to modernize our various motor applications as rapidly as possible, and during the past two years, our efforts along these lines have ben very noticeable.

"Without question, our efforts along these lines have resulted in much lower maintenance costs, increased production, and also a lower inventory of spare parts. Every effort which we have made toward standardization and simplification, has resulted in improved conditions in our particular industry."

There still are plants, many of them, whose transmission systems are an eyesore, both as to appearance and as to efficiency. Excess friction load is no more visible to the eye than tainted drinking water. The effects of the latter show up on the illness and attendance records, but the effect of the former only shows up where accurate and detailed power costs are kept. A slipping belt, in rare cases, needs only proper belt dressing; much more likely, it needs engineering attention looking toward a more efficient drive. A drive that seemed right ten years ago, or five years ago, is by no means necessarily "right," today. Aside from the probability that there is now available a more efficient—and therefore profitable—method, unless the driven machine in an exception, it is being pushed on a heavier production schedule than it was five or ten years ago.

THERE is no universally "best" belt, pulley, chain, gear, speed reducer, or other transmission device. Individual drive is no cure-all, nor is group drive. Chain drive cannot displace belt drive under certain conditions; nor can belt drive supplant chain drive under certain other conditions. Antifriction bearings cost more than plain bearings, but their use results often in immense savings, not alone in power, but in maintenance and in eliminating time losses; yet there are conditions where they cannot efficiently compete with oil-less bearings, conditions where they cannot efficiently compete with babbitted or plain bearings.

The important thing for the plant engineer to keep in mind, is that for every drive in his plant there is available an efficient solution; sometimes, a choice of several different ones. Unless he is taking advantage of the most up-to-date practice, and keeping in close touch with developments, he is overlooking a bet. And, in these highly competitive days of low-cost production, he simply cannot afford to overlook any bets.

Finding the BEST BELT *for* SEVERE DRIVE CONDITIONS

By WILLIAM STANIAR

Chairman of the Advisory Board, Power Transmission Association; Power Transmission Engineer, E. I. du Pont de Nemours & Company and General Motors Corporation

HYPOTHETICAL cases of mechanical transmission difficulties and their remedies are to a certain extent beneficial to industry, but actual difficulties and the methods employed to solve them are extremely valuable because they generally fit a situation that is causing worry to the plant engineer and a loss in production to the company. Atmospheric conditions such as acid fumes, heat, steam, dust, grit, and moisture, and mechanical conditions such as high ratios, high speeds, short centers, and oil exert a heavy toll on belting. In the present article, practical cases governing some of these conditions will be discussed, rather than suppositious ones.

Belting operating in an atmosphere charged with the mists or vapors of corrosive acids such as sulphuric, nitric, hydrochloric, bromic, etc., is a source of mechanical power transmission loss unless the proper type is employed for the acid condition involved. Certain belting substances succumb rapidly to the action of acid fumes, particularly when such fumes are combined with other atmospheric conditions such as steam and moisture. The result varies with the character of the belting material.

Leather, unless especially tanned and treated, is rapidly burned by acid action. Cotton fabric or yarn is either sulphonated or nitrated when acted upon by the fumes of sulphuric or nitric acid, resulting in its immediate destruction as a power transmitter; rubber compounds are made slimy by the action of nitric acid; and hair yarns are stiffened by the action of caustic and other alkalis.

It is evident, therefore, that great care based on experience and knowledge should be exercised in the selection of the type of power belting for acid operating conditions.

FIG. 1—AN EXAMPLE of "before and after" 30 days' service of a rubber belt operating in fumes of nitric and sulfuric acids.

* * * *

There is no power belting at present manufactured that will indefinitely resist the action of the corrosive acids. Therefore, it is simply a matter of selecting the type that will transmit power efficiently and economically for the longest period. Fig. 1 shows the effects of these fumes on rubber belt.

Fig. 1-A shows a section of the interior of a dye manufacturing building. The belt in the foreground is driving from a 35-horsepower motor to a line shaft, and although the mechanical conditions are good, the life of the belt is short and the maintenance is excessive.

At times dense mists and vapors of sulphuric and nitric acids prevail, causing rapid deterioration to almost any type of belt provided. These mists and vapors not only cause rapid destruction, but they also tend to lower the efficiency of the power medium while in service because of the surface effect on the belt. This surface effect or corrosion can be seen on the belt in the illustration.

The problem on this important

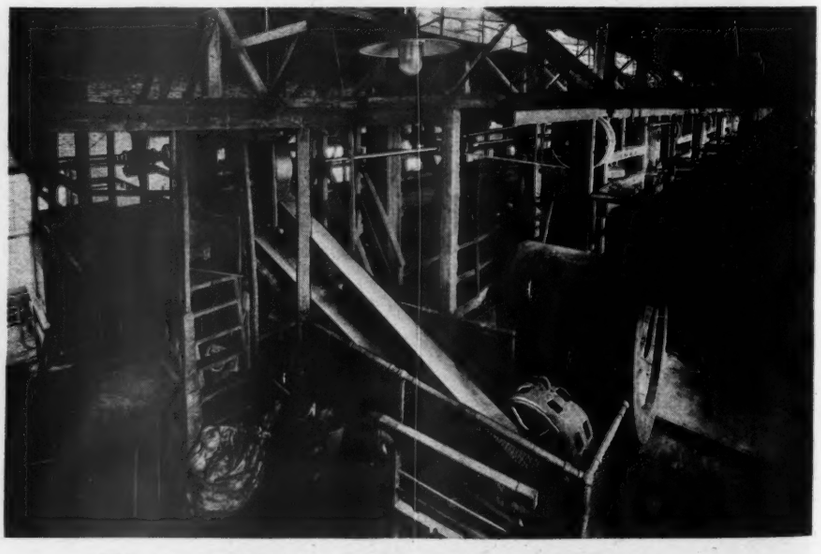

FIG. 1-A—A SECTION of the interior of a dye house, where acid fumes are prevalent. Note the acid burns on the belt in the foreground.

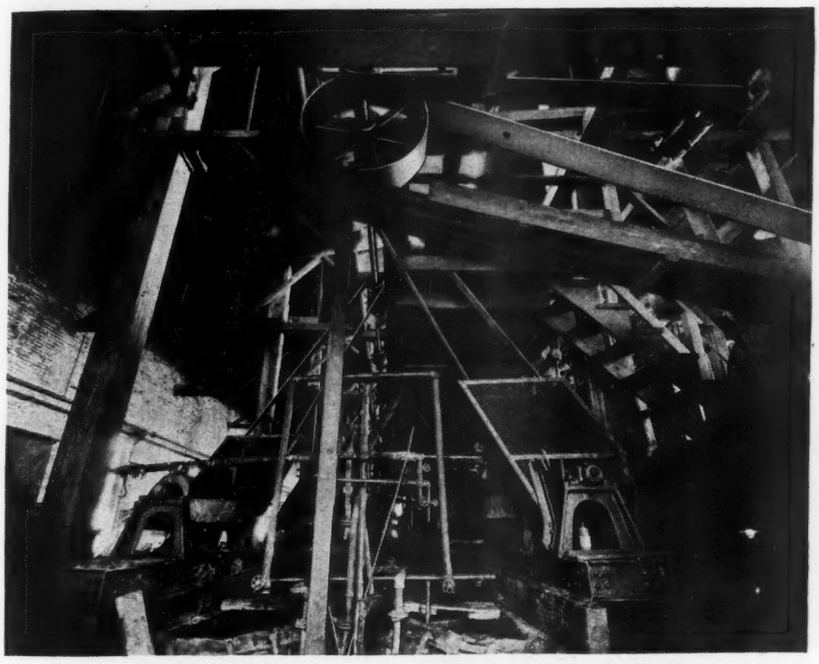

FIG. 2—ANOTHER SECTION of the dye house of Fig. 1-A. Here, shifting belt drives are required, and this complicated the problem of finding a suitable type of belting.

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drive was to obtain a belt that would give the longest life, the most efficient power transmission with the lowest maintenance. This was accomplished by months of testing of various belting substances with the result that a solid woven hair and cotton type of belting proved to be the best.

In Fig. 2 is shown another section of this same dye manufacturing building, where shifting belting is employed to drive mixing vats. The chemical fumes from the vats consist of a mixture of nitric and sulphuric fumes and are intense; therefore, the life of most all types of power belting on these drives is short.

Again the problem was to select and install a type of belting that would give reasonably long life, good power transmission, and low maintenance. This problem was solved by testing over a period of months and, based on the transverse resistance to shifting, it was found that a special acid-resisting frictioned ply belting reinforced with metallic staples placed longitudinally gave the best results.

Belting problems such as these cannot be solved by snap judgment. The solution for the longest life and lowest maintenance is possible only by the testing of various belting substances over a period of months.

The first belting tested on the drives cited gave a life of 15 to 30 days with considerable maintenance, while the types finally installed as a standard, based on the process of elimination, gave a life of 9 to 10 months with very little attention.

* * * *

Leather belting of any type should not be employed on drives operating under such atmospheric conditions as described. Certain types of fabric and hair beltings are most suitable.

From an atmospheric standpoint, grit or dust and heat are almost as disastrous to power belting as the mists or vapors of the corrosive acids. In many industrial operations abrasive grit or dust is prevalent, and unless a type of belting is employed which is impervious to the penetrating action of such substances premature destruction occurs. The average grit or dust produced by various industrial operations is abrasive. Therefore, when such material enters and is imbedded in certain types of belting a cutting action to the fibers of the belt results.

Leather and friction surface rubber belting are more impervious to this action than most belting materials because their structure resists penetration. The solid woven cotton and stitched canvas types should be guarded against where these conditions prevail.

Heat above normal temperatures, such as 110 deg. to 300 deg. F., is another destroyer of belting unless the proper type is employed. In actual machine or production shop operations very little consideration need be given heat in its relation to belting performance and life, but in miscellaneous industries such as foundries, chemical plants, and drying establishments, it is an important factor because certain types of belting succumb rapidly to its action.

In rubber friction cotton duck ply belting excessive heat has a deteriorating effect on the rubber friction, which results in a weakening of the adhesive medium between the plies and naturally shortens the life of the belt. In a type of belting which employs balata gum as an adhesive agent for the cotton duck plies a temperature of over 110 deg. F. will melt the gum. Such action quickly destroys this type of belting.

There are, however, types of ply

FIG. 3—A TYPICAL modern foundry. The problem, in cases like this, lies in meeting conditions of grit, dust and heat.

constructed belting which will resist the action of heat to approximately 200 deg. F. The action of excessive heat should be guarded against when the use of the impregnated types of solid woven cotton, hair and cotton, and stitched canvas belting is contemplated because the heat has a tendency to melt out the impregnating compounds. Based on the fact that these types depend to a great extent on their compounds for their power transmitting ability, it is obvious that a melting out will materially reduce the efficiency and life.

Leather belting of the regular oak tanned type fabricated with ordinary glue should not be employed in temperatures over 115 deg. F., because such heat has a melting effect on the glue and ply separation is the result. Leather belting fabricated with a waterproof cement will stand somewhat higher temperatures, to 140 deg., but it is a dangerous practice. Leather belting made of special mineral tanned leather should be used where temperatures above normal such as 110 deg. to 200 deg. F. are to be contended with.

Fig. 3 shows a modern foundry which presents a typical example of belting being exposed to grit, dust, and heat conditions. Some foundries have few belt drives, others have many, but regardless of number, the drives are important and the selection of belting type should be given serious consideration. Based on the fact that in foundry practice grit and heat are present, testing over a long period has demonstrated that leathers of the special tannage variety are the most servicable, when in close proximity to the heat, and friction surface rubber or balata when it is more a matter of grit resistance.

Another difficult drive is a hot metal saw. A drive of this character is nothing less than a positive destroyer of almost any type of belting, because such belting is called upon to transmit high power at high speed over small diameter pulleys, and under the atmospheric conditions of abrasive metal grit, and intense heat. Therefore, in circumstances such as these the greatest possible judgment based on experience should be exercised when a selection of belting type is made. Special tannage leather belting should be used exclusively on this type of drive.

Belting operating in any industry must contend with the action of moisture because it is present to a limited degree at all times in the atmosphere. However, atmospheric moisture as a rule has no effect on power belting other than that of shrinking and stretching. If excessive, it can open the plies of an ordinary glue cemented leather belt. As an enemy of power belting the term "moisture" signifies wet and sloppy conditions such as are found in paper mills, pulp mills, dye plants, canneries, chemical works, etc., where belting is subjected to induced high humidity and the actual contact with water.

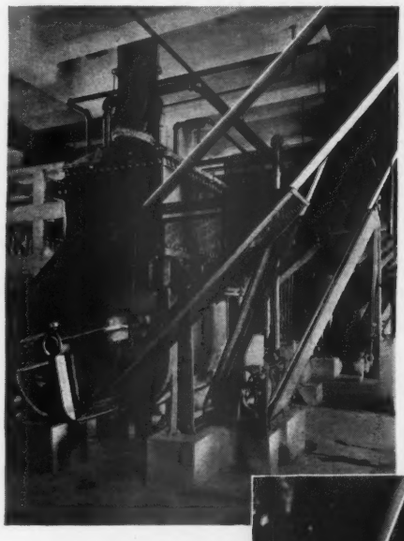

FIG. 4 — TYPICALLY wet, sloppy, steam conditions surround this drive in a chemical manufacturing plant. Quite different from Fig. 4, these conditions are none the less punishing unless the proper type belt is selected.

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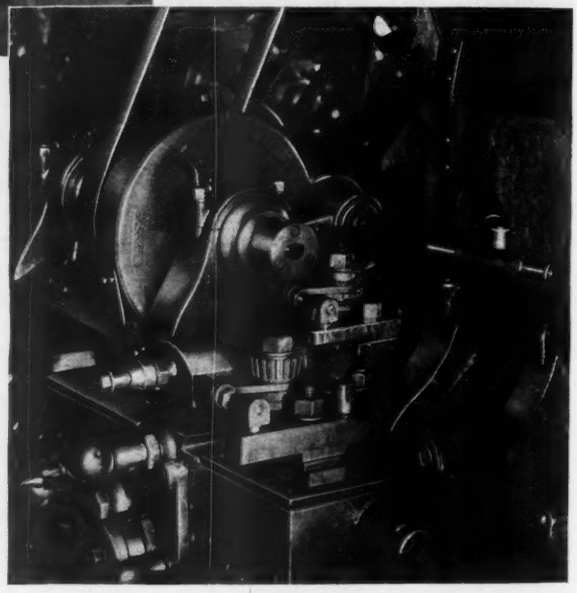

FIG. 5 — A TYPICAL machine tool drive. In such cases as this, it is oil which constitutes the chief hazard to long belt life.

Moisture of this degree is disastrous to regular oak tanned ordinary glued leather belting. It immediately causes ply separation, because such glue is soluble in water, and it has a stiffening and hardening effect on the leather. Therefore, where moisture is present, this type of leather belting should not be considered.

As a remedy for this condition, a waterproof leather belt has been developed, the leather of which is specially treated to resist moisture and the fabrication is made with a cement which is insoluble in water. A belt of this type can be operated immersed in water if necessary.

Cotton duck ply belting such as friction rubber and balata will resist the action of moisture just so long as the rubber friction or balata gum protect the cotton fabric. If these types are to be used in wet and sloppy conditions, care should be given to the relation of number of plies to pulley diameters and speeds because not only does this factor influence their power transmitting ability, but it also tends to crack the rubber friction or balata gum which allows the moisture to penetrate to the cotton fabric. The moisture then becomes trapped between the plies, causing a rotting of the cotton fibers and consequently, destruction.

Severe moisture has a tendency to make solid woven cotton and canvas belting soggy, which is not an advantage to power transmission.

Wet steam has about the same effect on power belting as ordinary moisture with the exception that it usually envelopes the medium in a cloud of moisture. Therefore, if the belting cannot resist, destruction is rapid.

Belting operating in close proximity to live dry steam must resist heat and, therefore, must have the necessary resistance to heat, as discussed a few paragraphs back.

Fig. 4 illustrates a wet, sloppy and steam condition of frequent occurrence in the average chemical manufacturing plant. There is an atmospheric condition of constant moisture due to the fact that the

process of manufacture necessitates large volumes of steam and water which cannot be entirely held in check. Therefore, the belting must suffer, and unless it is of the type that can stand this punishment its life is short, maintenance is high, and production is retarded. Testing over a long period has demonstrated that waterproof leather or friction surface rubber belting are the most servicable for conditions such as these.

In large machine and production shop operations where the group belting system of power transmission is employed, there are of necessity large numbers of individual belting installations which are in most cases continually subjected to the action of mineral lubricating oil. This material is the chief hazard to belting operations in the production shops of the country, because it is almost impossible to keep it from contacting the belting. Mineral lubricating oil is an absolute essential in all walks of mechanical operations. Therefore, based on the fact that the oil condition must be eliminated, it is necessary either to protect the belting from its ravages or to use a type of belting that will resist its action for the longest period of time. Mineral oil not only causes rapid destruction of certain types of belting, but it also causes power loss to all types because of the slipping effect when retained on the surface of the belt.

In most machine and large production shops leather belting is used more than any other type, and one of the chief causes for this is, no doubt, its general resistance to the action of mineral oil. Mineral oil will finally rot all tannages of leather, but it requires a long time for complete disintegration to take place so as to render it unfit for efficient uses.

After leather has become soggy by the penetration of mineral oil it can be entirely freed from this element by the gasoline cleansing method. This is not possible with any other type of power belting. Leather has the ability to absorb surface oil, therefore, is not so liable to slippage from surface oil as other non-absorbing types of belting material.

Friction surface rubber belting has never become universal in production shop driving, particularly because of the presence of mineral oil. Mineral oil has a rotting effect on rubber; therefore, the average life of this type in machine tool driving practice is short. If a rubber belt becomes soggy under the action of mineral oil it cannot be salvaged.

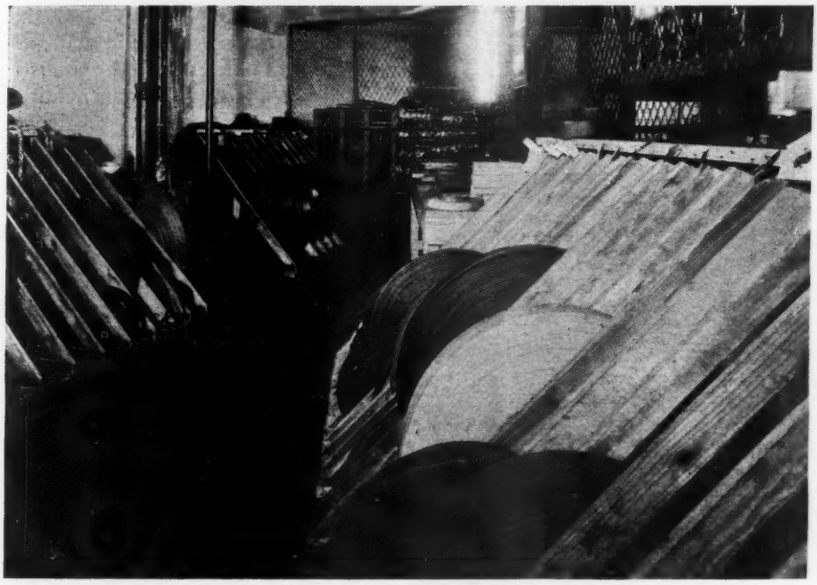

FIG. 6—PROPER STORAGE of reserve belting has a great deal to do with the life and service of belts. This storage room is in the plant of the Oakland Motor Car Company.

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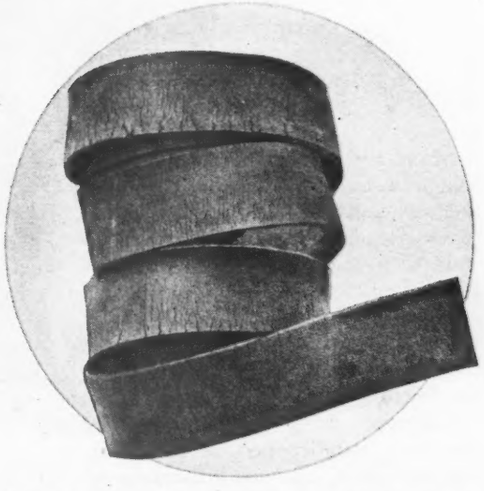


FIG. 6-A—NOT SERVICE hazards, but careless storage, ruined this leather belt by drying it out and causing the cracks which are plainly visible.

The solid woven and stitched canvas types of impregnated power belting are not as a rule serviceable, because mineral oil has a tendency to wash out the impregnating compounds. The life of these types, therefore, is short.

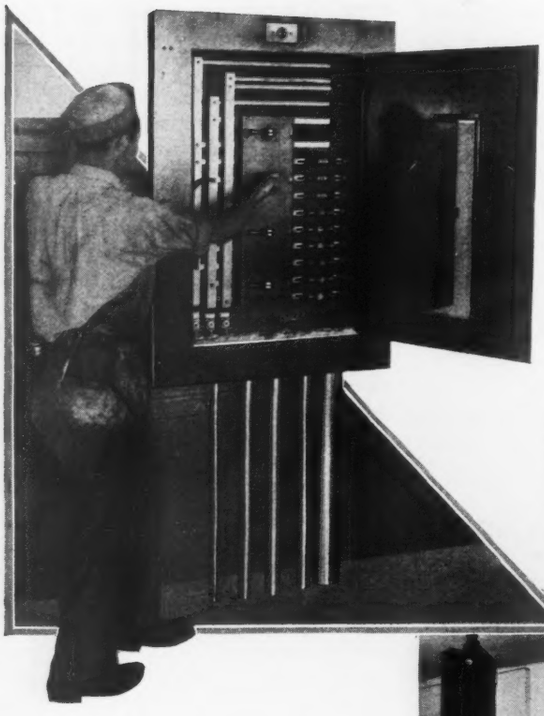
There are many cases in shop practice where oil is prevalent, namely, leaking clutches, leaking loose pulleys, and the throwing of oil from automatic turret lathes, but one of the greatest oil hazards to belting is hand shifting on such work as lathe and milling machine operations. The operator's hands naturally become coated with oil which is imparted to the belt when he uses his hand for shifting purposes.

Fig. 5 shows a typical automatic machine tool drive. It can be readily seen from the illustration that the oil conditions are severe. Many types of belting have been tried on this particular operation, and it has been found that leather is by far the most economical and efficient for drivers of this type.

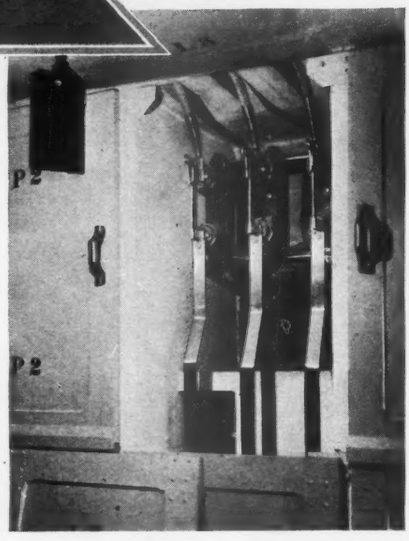
Wherever belt drives exist, spare belting must be kept in stock against emergencies. It was common practice, not very long ago, to keep such belting wherever there was room; often, merely flung on the floor of a store room, together with cans of oil, grease, and what-not. In other cases, belting was kept adjacent to the boilers.

Fig. 6-A is an un-retouched illustration of a belt that has never been in service; and never will be, because its life has been destroyed by improper storage. It not only pays to find the right belt for each drive, but it pays to store spare belts in such fashion that they will be found in good condition and, ready for service when needed.

Light Drive
POWER



LIGHTING CIRCUITS are controlled from central locations on each floor. The doors of this Trumbull cabinet are opened to show what emphasis is placed on safety.



DISCONNECTING switches are installed in all lighting as well as in power circuits.

CONTINUITY OF SERVICE is the first consideration in the development and installation of any system that has for its purpose transfer of energy. In most plants today, however, economy and efficiency are the favorite watchwords yet it is seldom possible to obtain and maintain them within prescribed limits unless the system operates on a continuous trouble-free basis.

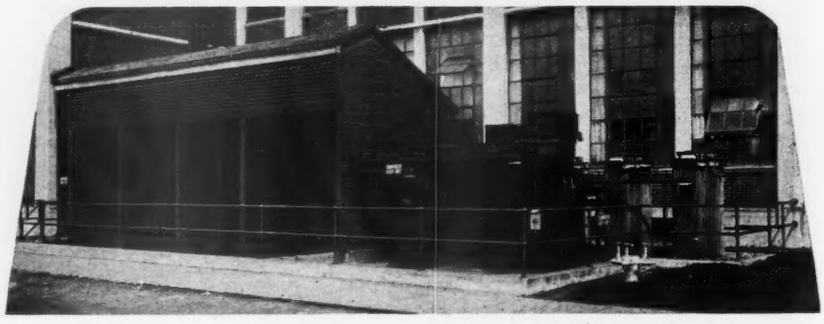
Building-in, so to say, continuity of service is but a stepping stone to the end that the economical and efficient results of operation will justify the selection of the equipment and until facts may be presented, in case there is no precedent to follow, one factor should not be sacrificed for the sake of the other.

Since no two plants are exactly similar, many engineers take the attitude on controversial points, that the results depend upon what is there to start with—and that is true to a certain extent. Take for instance the case of water-powered industries where the plant has expanded beyond the ability of the water wheel to carry the friction load.

Likewise, many a plant engineer has been handicapped in modernizing his plant equipment because of existing equipment rather than from a lack of improved devices which have made their appearance on the market within the past few years. The fact that it costs money to bring equipment up-to-date deters management in a good many instances. "It has served us four years, it is dependable and it has, in so far as we can determine, many more years of useful service," they say. The fact that it has "dependability" alone, satisfies their conscience as to its efficiency. It must be efficient or it wouldn't be dependable! Replace it? There is no economy in that, so get along with it the best you can.

Not a few engineers will recall from memory's recesses similar parallels in the efficiency *vs.* economy argument. End to end they would fill many volumes, nevertheless, it is not fair to place all management in one category, for ours indeed, has been not only sympathetic but progressive to a point where the industry at large could obtain the benefits of our experiments. Too much standardization spoils incentive and there must be a tremendous lot of incentive in industry else all plants would be similar and uninviting, for in the transfer of energy whether by mechanical means or by electrical means, especially in the distribution of power for light drives this dis-similarity is evident in the equipment you have to start with and what you must provide for future expansion.

Incidentally the problem is most simple, if the plant is a unit with a fixed production, but where it expands 63 per cent or more over the original installation, and there is a possibility of this figure increasing, the problem becomes more complicated and, no doubt, more difficult to solve. Power distribution is not just a matter of calculating loads and cable sizes. It involves just as much procedure and planning as any other device in the production process. In theory the principle is applicable to all plants; however, the application differs in a good many ways, and



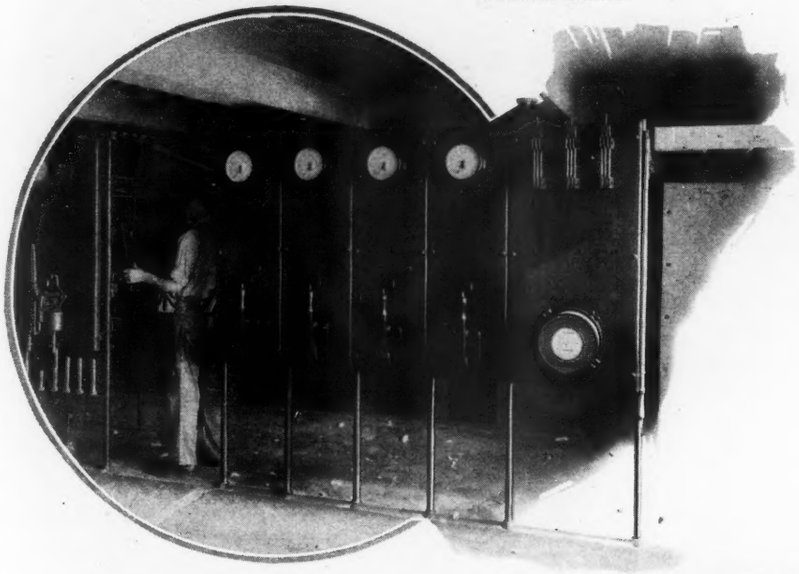
TRANSFORMER installation that provides 550-volt service for equipment in the four-story mill.

* * * * * * * *

DISTRIBUTION

By H. A. AREY
Plant Engineer,
Naumkeag Steam Cotton Company,
Salem, Mass.

CLOSE-UP VIEW of panels in balcony control room showing the vertical bus at the right and how the power is controlled in these independent substations. The five-panel section at the right controls all overhead-mounted motors.

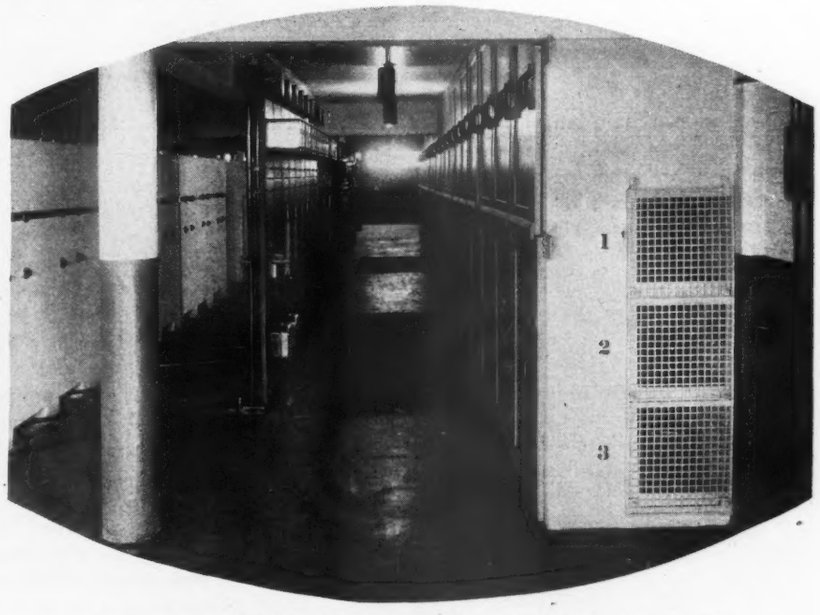


although our system of distributing electrical power to light drives serves our purpose, there is the possibility that it would be impracticable for others to follow. With it, we have incorporated as much safety as possible, and as much flexibility as is necessary without sacrificing the continuity that is the paramount requisite.

The Naumkeag was unfortunate, and perhaps fortunate, in having a disastrous fire about 14 years ago in which we lost practically all of our equipment which for the greater part was mechanically driven. Electrical drives were then just entering our field and we had taken an active interest in their development. Our pioneering showed us new methods of application which are recognized today as good practice. Be that as it may, we admit the fact, that no matter what has been accomplished in the past, there is a better way to do it, somewhere in the future.

On this premise we set about our business of equipping a new plant for which we co-operated with the best talent available, and that is possible in any line of endeavor. No one can ever expect to know it all. We knew what equipment was needed for a certain production, consequent'y we knew what floor space was required. Conclusions of this kind apply to any plant because the equipment to be used is available. Knowing the equipment and what it is capable of producing is but a stepping stone to the power required to drive it, and summing up all the power requirements of all the machinery gives you the total load that must be handled for a certain production. If provision is to be made for future expansion, the ultimate figure for production interpreted into power requirements will be naturally the starting point of the calculations. This is not done, however, in every case but it represents the best up-to-date practice. In one way or other some allowance must always be made for emergency or expansion whether it is in cable duct, cable, transformers or switch room.

The locations of the equipment in the various buildings and the various floors will determine the necessity for feeders, the size of which will depend upon the load to be carried and if extra copper is advisable to accommodate probable additions. Motor leads are provided to withstand capacities in accordance with motor name plate readings, plus a certain amount which may be determined by referring to Underwriters tables. The determination of all this information is the procedure that is necessary in distributing power. In most cases, vo'tage selection is a matter of personal opinion based on previous experience, and here we standardized 220- and 550-volt equipment, although, in some instances 110-volt



MAIN SUBSTATION controlling all power distribution that will keep pace with plant growth. The switchboard section in the foreground may be extended considerably to accommodate additional plant circuits.

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service is provided for auxiliary devices on newer equipment.

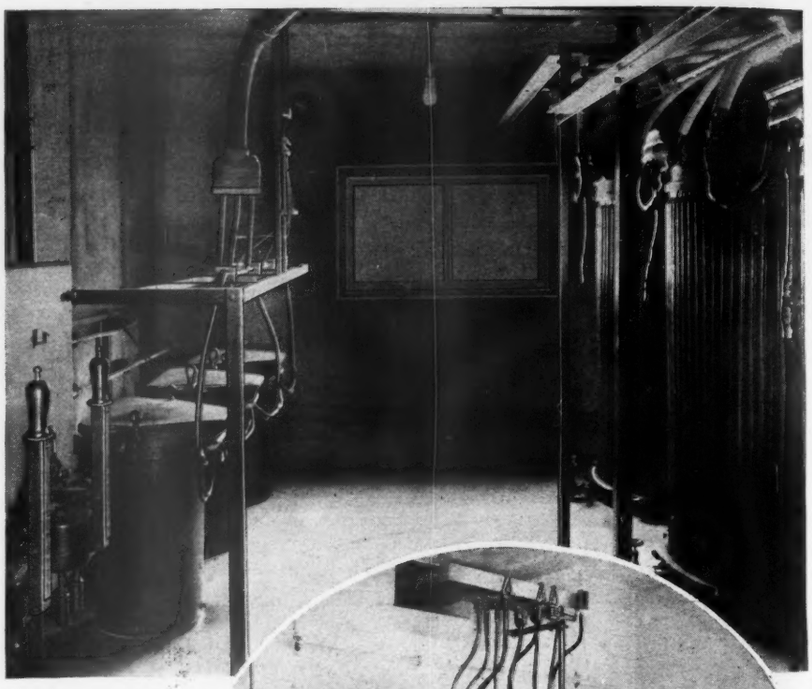
Lighting is maintained separately throughout the plant and controlled from the same source as power. The control panels and distributing panels for various circuits are shown in accompanying illustrations.

Up to this point the approximate total load is known, simply by totaling the motor and lighting loads, but one must not overlook the fact that the small a.c. motor used in light drives in every plant is not as efficient as its big brother and besides the power factor is much lower. When you purchase power there is meaning to power factor especially if it hangs around 70 per cent. At this point, if you will permit me to digress, there is a difference in operation when you generate your own power, and no plant is entirely immune. For instance, at the bleachery plant, our 750-kva. turbine was fully loaded, but at a very low power factor due to the inductive nature of the load. As long as there was no need for additional power this condition was permitted to exist but when the opportunity arrived it was comparatively easy to remedy it with synchronous equipment that not only performed the work required but aided to correct power factor, thus relieving the generator from its overloaded condition which consisted chiefly of wattless energy.

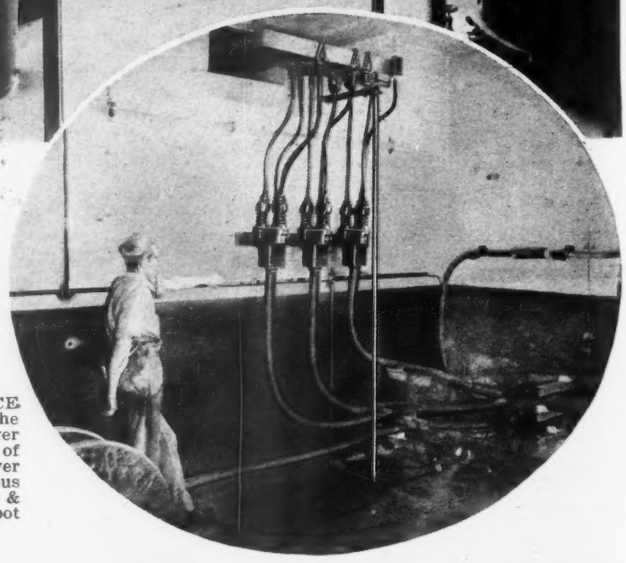
At the mill, we have approximately 9,000 hp. in light motor drives varying from ½ to 35 hp. in capacity, installed in two main buildings; 6,500 hp. in one and 2,500 hp. in the other. In the former, the load is divided between four floors and the basement, whereas in the latter, all equipment is found on one floor and in the basement. Having available the power requirements for a certain capacity, corrective apparatus was applied, based on the power factor desired, to avoid complications in our contract.

Realizing the need for compressed air for various services, air conditioning chiefly, and knowing that compressors are ideally adaptable for synchronous-motor drives, we equipped them to satisfy both conditions, that is, to do useful work and to provide the needed power factor correction.

From this point we were ready to investigate the facilities for power distribution to several thousand motors. We devised a switch tower in conjunction with the four-story building, in the basement of which was the original distribution center for incoming and outgoing circuits. However, we have outgrown this location and are now situated in the basement of the cloth building where we may expand for years to come without exceeding the space allotted.



BASEMENT transformer and switch room, one of seven serving the equipment in the single-story building.



CABLE ENTRANCE in the basement of the four-story switch tower showing the method of transferring the power from cable to open bus work by means of G & W non-magnetic pot heads.

The space allotted to substation equipment is approximately 30x60 ft., with the switchboards, switch cells and buses parallel to the longest dimension of the room. Beginning along the center line of this room, the switchboards extend to the right and left for incoming and plant distribution power respectively.

The incoming service is handled by eight 500,000 circ.mil underground cables, two of which were added in 1927. These cables enter in the rear of the room through ducts in the ceiling passing down to the cell compartments containing the oil switches, then to the ceiling ducts over the panels to the main buses lettered *1, 2* and *3* in the compartment at the right in the illustration.

This main bus is split for totalizing metering purposes. The circuits on the left find their source in the main bus and are identified by marking the inclosures *P* or *L* to indicate a power or a lighting circuit with the number following to identify the circuit. These markings are found on the doors of the compartment as shown, as well as on the ceiling above them and on the switch panel, so that no mistake may be made when dealing with any circuit. The plant circuits rise vertically from the bus through disconnecting switches and through ducts in the ceiling back over the switch panels to the switch cells, from where they emerge in floor ducts and continue in underground conduit using Simplex lead-covered cable to the various buildings. Where the feeder is just laid in the ground, steel, armor-clad cable is used. In the basement of the four-story mill, and in similar manner in the one-story mill we dig a trench, lay the cable and cover it with sand.

Directly above the feeder, and on

cross beams, if the location happens to be the cellar floor we indicate with a suitable legend the location of this feeder. The purpose is to acquaint employees with underground electrical circuits. Yard employees especially respect this marking when doing any excavating work.

Since all buildings are connected with an underground passageway or tunnel, we have utilized them to some extent in carrying distribution circuits but not for the express purpose thereof. The feeders take the most direct route to the distributing center from the substation. All circuits are metered on the main panels, and a recording frequency meter keeps tab on the three-phase 2,300-volt incoming power.

The reason for this number of circuits is due to expansion and a desire for flexibility together with the necessity for continuity of service.

Continuing underground we distribute to switch towers wherein are located power and lighting transformers. The transformers that serve the spinning mill are located outside as shown on page 544. The high-tension feeders, however, enter through the basement of every building where we again provide control of the entire service.

Three 1,250-kva. 2,300/550-volt transformers in addition to supplemental transformer equipment provide service to the 750 motors installed in the spinning mill whose total load is approximately 6,500 hp.

The original transformer installation now in the semi-inclosed structure to the left, whereas the outdoor-type transformers represent the later additions to accommodate the 63 per cent increase of load.

These transformers are controlled in a basement switchroom shown on page 546 but the panels cannot be seen in the illustration. The primary feeders are in cable ducts to and from the switch panel and to the transformers.

The 550-volt secondary circuits are brought back to this switchroom where they terminate in a vertical bus that feeds every floor in the building. As a means of distributing power to distribution centers we feel that the vertical bus satisfies every requirement. Of course, this method is possible only when the building exceeds one story in height.

Since we had planned this building to utilize electric service throughout, as much thought was given to the location of the equipment as to the means of controlling it from central points. We followed the scheme of utilizing switch towers throughout, even with the single-story weave shed which is served from seven such towers containing 200-kva. banks each.

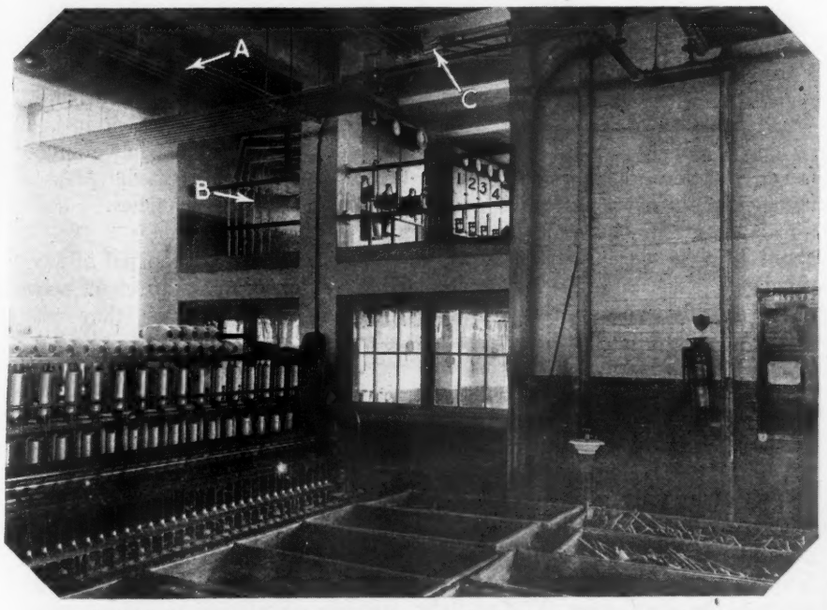
Starting at the first floor, five 4x¼-in. copper straps per phase are used, decreasing in number by one until at the top floor two straps per phase will be found. This bus is in an inclosure approximately 2x2½ ft. in the corner of the tower as shown on page 545, and separated from the room by transite.

On each floor there is a balcony about 15x20 ft. containing the control equipment for the entire complement of drives on that floor so located that from it one can overlook the equipment in operation.

Where overhead drives constitute the equipment on that floor the balcony control room contains only five panels, one totalizer and four distributing panels, but for the floors that have both overhead and floor mounted motors additional panels will be found installed to the left of the standard equipment (5 panels) as shown to the right of the figure in the illustration on page 545.

The photograph reproduced on this page illustrates the way we serve the floor and overhead-mounted motors from the control balcony on that floor. The feeders at *A* have their source in the panels numbered *1, 2, 3* and *4*. These feeders extend one to each cardinal point of the compass serving the motors in that section of the building. At *B*, two sets of feeders controlled from the panels at the left are shown extending down through the floor to the ceiling of the floor below, just as at *C*, which feeders come from the floor above for the floor-mounted motors thereon, and in this manner all equipment on each floor is effectively controlled from the balcony control room. Open wiring with slow-burning insulation is used

(Please turn to page 594)



BALCONY SWITCHROOM containing control equipment for all drives on the floor. Each floor in this four-story mill is provided with a similar switchroom. The feeders at *A* are controlled from the switch panels marked 1, 2, 3, 4, and they serve all overhead motors on this floor. The feeders *B* serve the floor-mounted motors. These feeders go through the floor to the ceiling of the floor below just as the feeders at *C* are shown coming from the floor above.

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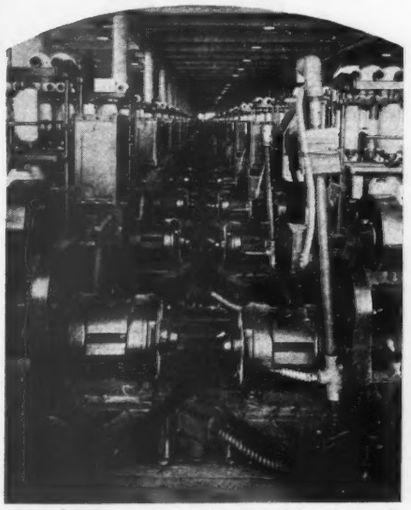


FLOOR-MOUNTED motors showing how the power is brought up from the ceiling of the floor below, through a junction box of Naumkeag design and make.

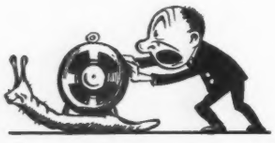
Plant Engineer's

Conducted by F. M. GIBSON, *Consulting Editor*
Plant Engineer at American Sugar Refining Company

THE TREATING of any commodity in bulk, with equipment in which there are comparatively few alterations in design, will always receive the greater consideration. Electric generators with their prime movers will be given a great deal of study and be selected upon a very slight margin of difference in efficiency. But when it comes to transmission, one has to consider a large number of smaller units. In the aggregate they will transmit just as much power as the larger unit, but the time required to give proper consideration to each unit will aggregate much greater than the consideration of the generator.

Engineers know that it is worthwhile to devote this time, but fail to do so for two reasons. One reason applies to the type of engineer who fails to find the interest in smaller things that he finds in large ones, and it therefore becomes irksome to him. The other reason is more generally true, and that is, the rush of the job.

When the management votes funds for an installation, they want to see things move, they want to see actual material being erected on the job and



are impatient of the time devoted to layout study which shows no progress in erection of equipment. The selection of the generator or the equipment to be driven is the major consideration and, when that is determined, it seems to be the popular opinion, from the management down, that everything is settled and that there is no reason why installation cannot start at once.

Being harassed, the engineer selects the obvious, and may or may not select the most efficient, system of transmission. Such conditions are faults to be corrected but to my mind they are not the greatest problem.

Transmission equipment and systems can be selected upon very definite information as to price and as to efficiency on the testing floor but the efficiency of that equipment under normal operating conditions is far from being definitely known. Every one expects that the operating efficiency will be less, but how much less should it be? Great importance will be placed upon one per cent difference in test floor efficiency between two pieces of equipment, but how

much consideration is given the drop in efficiency after a period of operation and how much would be known about it if it were given consideration?

It was only two or three years ago that one of our technical institutions began the study of the loss in efficiency due to wear in such an age old piece of equipment as the spur gear, and found that gears not considered too worn to be continued in service, had lost 30 per cent in efficiency. The results of these tests are not generally known. No such investigation, as far as I know, has ever been given to the worm gear. Will a slight amount of wear in the worm gear give a greater loss in efficiency than it will in a spur gear?

We have our opinions, but they are only opinions, not knowledge, and are not of any great degree of definiteness. Equipment is designed with a very definite knowledge of the effect of various methods and materials upon test floor efficiencies, but with very indefinite knowledge of their effect upon operating efficiencies.

Obviously this is due to lack of intelligent accumulation of operating data. There is not sufficient data of this nature in existence and what does exist is not well detailed or easily accessible. It is information sorely needed by the industrial engineer, and it would also direct designing engineers in the design of more serviceable and more efficient equipment.

The obligation to secure such information and the ability to determine its technical classification and dependability lies exclusively with the industrial engineer. This is his opportunity to elevate his profession by supplying a constructive need and to become recognized as an authority. It can be accomplished only by his own initiative. He must organize groups to standardize methods and formulas for securing data and to enlarge the field in which it is obtained. Local industrial engineers' clubs and free use of the press are the most effective agencies.

* * * *

One engineer is reported as saying that "engineering is an exact science but engineers do as they damn please." That may be so, but it seems to me that engineers depart from accepted practice because it is not applicable to their special problem, and not for the reason that engineering is not exact. It is the application of engineering that is at fault. Some years ago I had the problem of a belt drive in which heat was the controlling feature. These belts were driving centrifugal machines starting from standstill, accelerating to full speed, braking and stopping, in three minute cycles. They were 6-in. belts transmitting a maximum of 25 hp. running at a speed of 5,000 feet per minute, pulleys on 9-ft. centers with quarter turn and tightener. The brake operated on the inner face of the rim of the driven pulley, 17 in. in diameter, and the braking requirements were so severe that the rim was heated to such an extent that the belts were burned in a short period of time.

Conditions were such that the only remedy possible was to change the material of the belt. It was reason-

's Forum

able to assume that a woven belt treated with a heat resisting compound would stand the heat better than such materials as leather or rubber. I was informed from all sides that woven belt would stretch and contract. Also, at that time it became the practice of various testing laboratories to issue charts with curves showing the traction of

various kinds of belts, and these charts were not complimentary to woven belts.

A number of woven belts were tried and one was found that had no more stretch than leather, in fact a little less. It was also discovered that after the belts had been conditioned to service, the traction of the woven belt was greater than that of other belts; the more rapid acceleration of the machine being evident to the eye, though no one ever thought of using a tachometer to determine how much faster.

It was a promising start, but there was also grief in the pulling out of the lacings and in the wearing of the edges. The manufacturer of the belt went the limit in the development, and eventually produced a belt that would meet the requirements. It took a period of six years to accomplish results, but the longer service of the belt has repaid all the time and expense. No, it is not the question of an engineer doing as he pleases, but it is more like the boy who wished that he had a dollar to go to the circus and the boy who wanted to go to the circus so badly that he went out and found a way of earning a dollar.

* * * *

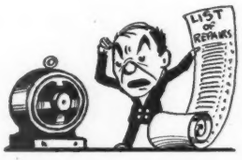
A few years ago much expense was incurred by purchasers of equipment in checking the manufacturers. Visits to the manufacturer's factory were made, to inspect the equipment during construction, and the equipment was tested when received.

Manufacturers improved their methods of inspecting and testing so that the practice of checking up by the purchaser decreased. It was expensive and the purchaser began to put more faith in the manufacturer, particularly in standard units.

Naturally, it is expected that the manufacturer occasionally will send out a piece of equipment, unintentionally, that is below standard. But there have been so many unfortunate experiences within the past year that one wonders how far he should go in checking up the manufacturer. These experiences are from reliable engineers and a few might be mentioned.

One engineer purchased four centrifugal pumps from a large manufacturer. They were ordered to the same specifications and were intended to be interchangeable. The pumps were put in service without being opened. When opened for routine inspection, it was found that there were three different designs of impeller in the four pumps.

Another company purchased two large motors from one of the largest



manufacturers and put them in service without testing. In one year the repairs on these motors cost more than one-half of the purchase price. Eventually they were tested and it was found that at full load the temperature rise was 70 deg. C. instead of 40 deg. C, as specified.

As an extreme case when special attention was given to design, mention may be made of a high-pressure boiler and turbine installation that was so unusual as to attract almost nation-wide interest. The pressure specified for the boiler was somewhat higher than that specified for the turbine. Yet through some error the turbine was designed for the pressure specified for the boiler!

There are many systems of telltales and automatic alarms devised, often at considerable expense, to control the height of liquid in tanks in order to prevent overflowing. The most economical one that I ever knew was originated by a Polack tank watcher on the night shift. Liquid was supplied to the tank in a constant flow and drawn off at varying rates. When the tank threatened to overflow it was his duty to notify another department to stop the supply.

It was one of those jobs that encourages sleepiness. This fellow would go to sleep with one arm hanging in the tank and when the liquid at 200 deg. F. rose high enough to submerge his fingers the alarm was automatic and positive. It would be difficult to find a simpler device, with less mechanical maintenance.

* * * *

George Felton tells of an experience which illustrates the importance of minor transmission equipment. On his return from an extended trip, he found that the manager and the master mechanic had decided that a motor driving a group of machines was too small and that steps toward buying a larger motor had been taken. The consistency of the material processed in the machines had been changed, causing the intermittent peak loads to be greater, so that the circuit breaker would kick out. The interruptions thus created interfered seriously with production. After sizing up the situation he connected a curve-drawing wattmeter, tied up the circuit breaker and watched the operation. It was found that the peak loads were not high enough or of sufficient frequency nor of sufficiently sustained length to injure the motor. Another circuit breaker with greater time element solved the problem, and the cost of a new motor was saved.

What to Use—and Where for MECHANICAL

This compendium has been compiled and digested from the manuscript of William Staniar's forthcoming book, "Mechanical Power Transmission," embodying the author's experience of some fifteen years in that specialized work

Belting

Regular Oak-Tanned Non-Waterproof Leather Belt is made in single, double and triple ply and in any width required. Being fabricated with hot glue, it is subject to attack by water or atmospheric moisture. Its use should therefore be limited to dry conditions or to installations where cheapness is paramount. See Table on page 552.

Waterproof Cemented Oak-Tanned Leather Belt is made in plies and widths the same as the non-waterproof type, but is fabricated with a pyroxilin cement impervious to moisture and is dressed with oils which make the leather itself moisture resistant. Its cost is approximately 10 per cent higher than non-waterproof. See Table.

Special Tannage Leather Belt is the result of a demand for something better than oak tanned leather. Made in the same plies and widths, its power-transmitting ability is greater; having a higher coefficient of friction and a higher tensile strength, as well as extreme flexibility. The special mineral tanning, together with its being fabricated with pyroxilin cement, make this type of leather belt moisture, steam and heat proof, and resistant to acid fumes. It costs approximately 50 per cent more than oak tanned leather. See Table.

Combination Oak and Special Tannage Leather Belt is made by joining one ply of each of these leathers to the other, flesh side to flesh side, by means of waterproof cement. The characteristics of special tannage leather are thus combined with the stiffness of oak tanned, permitting its use on stepped cone pulleys and shifter drives where ordinary special tannage does not offer sufficient resistance to transverse crumpling action. See Table.

Friction Surface Rubber Belting is made of strong cotton duck (28- to 36-oz.) impregnated with a strong, slow-ageing rubber compound forced into its interstices by calendar rolls. It is made in thicknesses from two to twelve plies and can be had up to 84 in. wide. See Table.

Stitched Cotton Duck Impregnated Belt, known as "stitched canvas," is made by folking together the requisite number of plies of heavy duck, stitching them together throughout their length, and then impregnating with compounds which render the belt resistant to moisture and other influences. There are various grades and kinds of this type of belting. The better grades will stand heat to 140 deg. F., and are suitable for a wide variety of drives. See Table.

Hair Belt is made from hair yarn of various mixtures of hair and wool with cotton. Selected camel's hair is considered best for the purpose. It is woven on high powered looms, under heavy tension, and then impregnated with certain heavy oils which preserve it and add to its frictional qualities. Its elasticity, frictional qualities, shock-absorbing power, extreme flexibility and resistance to oils, heat and acid make a valuable power transmitter. See Table.

Balata Belt is a distinct type of cotton duck ply construction, in which the plies are thoroughly impregnated with Balata gum and then bonded by pressure. Its practically stretchless quality makes it particularly suitable for heavy, hard-pull installations. See Table.

Solid-woven Cotton Impregnated Belt is made, with varying characteristics, by different manufacturers. The better brands of this type will be found efficient and economical on high speed spindle drives of machine tools and grinders. Except that this type is not acid-resistant, its characteristics compare with those of woven hair belting. See Table.

Light-weight Duck Ply Rubber Belt is made of a light-weight, closely woven cotton duck thoroughly frictioned with a rubber compound. It has many of the characteristics of regular friction surface rubber belt, but has greater resistance to ply separation. It is an efficient power transmitter.

Metallic Reinforced Cotton Duck Ply Belt is of foreign manufacture and is similar in construction to regular rubber belting, except that the plies are frictioned with a special cement and reinforced by metallic brads or staples, closely spaced in longitudinal rows. Owing to the acid-resisting friction compound, this type gives long life in corrosive acid conditions. Its low stretch and oil-resisting qualities make it applicable to practically all machine tool drives.

Special Type of Leather Belt. A recent development, of French origin, is the combination of soft, chrome-tanned leather strips riveted to a belt of leather or composition. The soft leather strips give an exceptional gripping quality, and the backing furnishes the requisite strength. This type is of special service on short center work, in eliminating the need for excessively tight belts.

Belt Fastening

Endless Belts are the most efficient from a standpoint of safety and power economy, but practical considerations limit their use. Unless there are take-up facilities on the drive, the initial stretch of the belt will require prohibitive shut-down periods for readjusting. The endless belt should not be used on quarter twist drives, on vertical drives without idlers, nor on any drive lacking center-to-center adjustment.

Laced Belt Joints afford the oldest known method of belt joining, and one that is by no means obsolete. Rawhide lacing, properly done, produces a belt joint that is both serviceable and durable. The modern wire lace, instead of rawhide, while it has not the life of the latter, produces a smoother joint. Each type of lacing, therefore, has its advantages, and the choice is a matter of individual conditions.

The Individual Wire-Hook Hinge Fastener has won a place for itself because of its speed and ease of application and because it provides an accurate, flexible joint. A row of individual wire hook loops is pressed into each end of the belt; the resulting wire loops are meshed, and a rawhide pin is inserted to form the hinge joint. Because of its ease and speed of assembly, this type of fastener is widely used on drives which require take-up inserts, or where for any reason it is necessary to unfasten a belt quickly. It is applicable to single and double leather and to fabric belts from two-to six-ply, but should not be used on belts more than 8 in. wide.

L POWER TRANSMISSION

The Pressed-Steel Hinge-Pin Fastener is made of pressed steel and when applied to the ends of a belt, it forms flat loops into which hinge pins are inserted to make the joint. Instead of rows of individual wire hooks, this type comes in strips which are cut according to the width of belt. Instead of a rawhide pin, two steel pins are used for the hinge joint, designed so as to give a rolling action on each other in flexing over the pulleys. This type, again, possesses the advantage of ease and speed of application. It can be used on belting not more than 10 in. wide.

The Riveted Plate Fastener combines great strength with light weight. It comes in sizes suited to the width belt to be joined, and the plates are fastened to the belt, across the joint, by means of split steel rivets which are hammered through the belt; affording a smooth surface on the pulley side. The plates are made of a special steel, and designed to conform to the curvature of pulleys of various diameters. This type is applicable to any width belt over one inch; to heavy, slow-speed drives; to double leather belting, and to fabric belt from three- to twelve-ply. It should not be used for idler installations, for high-speed small pulley drives, or on special tannage leather belting.

The Bolter Plate Fastener employs special bolts and washers for fastening a series of plates across the belt joint. It is especially strong in its grip and is particularly efficient on heavy fabric belts subect to heavy pull and shock loads. This type should be selected with care, to see that the size conforms to pulley curvature.

Hand-Applied Prong Fasteners, when selected with due regard to pulley curvature, provide a strong and efficient means of belt joining. They consist of pressed steel strips which present much the appearance of a row of double-pointed tacks or staples. The strip is cut to belt width, the points straddle the belt joint and are hammered through, clinching on the under side of the belt. This type is extensively used for general driving conditions, and affords a speedy means of belt joining without requiring special tools.

Modern Short-Center Drive Equipment

The Automatic Idler is the result of engineering research applied to the ordinary belt tightening idler. In this device, the fulcrum or idler pulley is scientifically applied in such a way as to increase the arc of belt contact automatically in accordance with the load. In effect, it actually wraps the loose side of the belt around the driver, and since belt stretch increases with the load, this wrapping action increases correspondingly. This device is applicable to bottom-pull or top-pull drives, horizontal or at an angle, and also provides a good solution to vertical drive problems, whether short center or not.

The Multiple V-Shaped Rubber-and-Fabric Rope Drive is an adaptation of the English system of multiple endless rope drive, but employs V-shape fabric-and-rubber belts operating on V-grooved pulleys. These belts are made endless by the manufacturer, in sizes according to the individual requirements. This system is an efficient power transmitter on short centers, and has shown excellent results on centers as long as twelve feet. It practically eliminates slip, when properly installed, as load tension operates to increase the adhesion of the V-belts in the V-shaped grooves. This drive can be had in power capacities from ½ to 2,000 hp. A drive of this type is, of course, reversible.

A Special Type Leather Belt is now available, which has successfully met short-center drive requirements, though it is not confined to short center work. It consists of a belt of leather or composition backing, with chrome tanned leather strips riveted to it, at intervals across the width, running longitudinally with it. The chrome leather strips give exceptional frictional grip, while the backing supplies the required strength. This type can be applied to the ordinary pulley, and affords a ready solution to many existing troublesome drives.

Chain Drives afford a solution to short-center drive problems, but it would be manifestly unfair to their all-around qualities, to confine them to this particular service. For that reason, a more extended discussion of the various chain drives will be found in a separate classification of this compendium.

A High-Ratio Short-Center Device with automatic belt tension, of foreign origin, has recently been introduced in this country. Ordinary short-center devices for belt drive cannot efficiently cope with ratios of from 15 to 1 to 30 to 1. Gear reduction units can, but there are cases where these may be too inflexible. The new device consists of a gear, pinion, pulley, spindle, and fulcrum arm. The gear is keyed on the driven shaft and meshes with the pinion on the spindle by means of a belt drive to the spindle pulley, the pinion's epicyclic movement around the gear wheel is restrained by the belt tension, so that continued rotation of the pinion will rotate the gear. Thus, correct tension is always maintained on the belt. The device has passed the experimental stage and is in successful use abroad, as well as in a few installations in this country.

Steel Shafting

Cold-Rolled Steel Shafting is widely used for line-shaft, jack shaft, counter shaft, and head shaft installations for power transmission. For ordinary use, its low cost makes it the logical choice.

Forged Steel Shafting is made from the ingot, by drawing under a steel hammer and then turning in a lathe to the required diameter. It is advisable to use forged steel where shafting of more than 6 in. diameter is required, because a stronger, more homogeneous metal structure is secured. Since the strength of forged shafting is some 50 per cent greater than cold rolled steel, it can be used in smaller diameters than the latter for the same power and speed.

Nickel Steel Shafting, of 3½ per cent nickel possesses remarkable ductility, elastic qualities, and tensile strength. In such service where carbon steel shafting fails as the result of fatigue, nickel steel has met the requirements perfectly. In spite of its higher cost, there are many transmission situations where this shafting would prove a real economy because of its endurance of shock loads which cause crystallization of carbon steels. Nickel steel shafting has almost three times the strength of cold rolled steel.

Bearings and Hangers

Solid Babbitted Bearings, of cast iron, babbit lined, are used on shafts or axles under 4 7/8 in. diameter, revolving at slow speed, where adjustment is unnecessary. Lubrication is by grease cup or oil.

The Split Flat Box is similar in appearance to the solid bearing, except that it is split longitudinally, the cap being held to the body by bolts. It is extensively employed where moderate powers and speeds are involved. This type has no adjustment other than a slight transverse one, due to the holes in the base being slotted. It should not be employed on shafting over 3 11/16 in. diameter.

The Plain Oiling Rigid Pillow Block is also of cast iron, babbitted, and has a cap which, in sizes from 2 11/16 to 15 in. diameter, is held by four bolts. This

A Ready Reference Chart of Power Transmission Belting

		Max. Belt Width, In.	Min. Pulley Diam., In.	ADAPTED TO				RESISTANCE TO							Light, Medium or Heavy Drives	Remarks
				Belt Shift Drives	Stepped Cone Pulleys	Automat. Idler Drives	Crossed Belt Drives	Mineral Oil	Cutting Compounds	Moisture	Steam	Acid	Alkali	Heat Above 115° F.		
Non-waterproof Oak Tanned Leather Belt	Single ply	5	3	½ to 3 in.	½ to 3 in.	No	Yes	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Light	Suitable only for dry conditions, as it will not withstand moisture. Under proper conditions, affords a cheap medium for power transmission.
	Lt. double	8	6	1½ to 6 in.	1½ to 6 in.	No	Yes	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Medium	
	Reg. double	2½ up	10	2½ to 10 in.	2½ to 8 in.	No	Yes	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Heavy	
Waterproof Oak Tanned Leather Belt	Single ply	5	3	½ to 3 in.	½ to 3 in.	No	Yes	Fair	Good	Good	Good	Poor	Poor	Fair	Light	Costs approximately 10 per cent more than ordinary oak-tanned, but is moisture proof, and therefore outlasts the other under average conditions.
	Lt. double	8	6	1½ to 6 in.	1½ to 6 in.	No	Yes	Fair	Good	Good	Good	Poor	Poor	Fair	Medium	
	Reg. double	2½ up	10	2½ to 10 in	2½ to 8 in.	No	Yes	Fair	Good	Good	Good	Poor	Poor	Fair	Heavy	
Special Tannage Leather Belt	Single ply	5	1½	No	No	When made endless	Yes	Fair	Good	Good	Good	Fair	Fair	Good	Light high speed	Costs approximately 50 per cent more than ordinary oak-tanned, but is waterproof, much more flexible, acid resisting, and has better gripping qualities.
	Lt. double	6	4	No	No	When made endless	Yes	Fair	Good	Good	Good	Fair	Fair	Good	Medium, high speed	
	Reg. double	Any width	6	No	No	When made endless	Yes	Fair	Good	Good	Good	Fair	Fair	Good	Heavy, high speed	
Combination of Oak and Special Tannage Leather		2 up	10	2 to 10 in.	2 to 8 in.	No	Yes if shifting	Fair	Good	Good	Good	Fair	Poor	Good	Heavy, slow speed	Combines the qualities of special tannage with the resistance to side pressure of oak tanned.
Friction Surface Rubber Belting	2 and 3 ply		3	Yes	Yes	Only when endless	Yes	Poor	Good	Good	Good	Fair	Fair	Fair	Light	Especially adapted to wet and sloppy conditions, as its strength is actually greater when wet.
	4 and 5 ply		4–5	Yes	Yes	Only when endless	Yes	Poor	Good	Good	Good	Fair	Fair	Fair	Medium	
	6, 8, & 10 ply		10–20–30	Yes	Yes	Only when endless	Yes	Poor	Good	Good	Good	Fair	Fair	Fair	Heavy	
Stitched Cotton Duck Impregnated Belt	4 ply		4	Yes	No	No	Yes	Good	Good	Good	Good	Fair	Poor	Fair	Light	Stitching minimizes tendency to ply separation. Impregnation renders it waterproof and resistant to oils. Is flexible and has good gripping qualities.
	5 and 6 ply		6–8	Yes	No	No	Yes	Good	Good	Good	Good	Fair	Poor	Fair	Medium	
	8 and 10 ply		12–20	Yes	No	No	Yes	Good	Good	Good	Good	Fair	Poor	Fair	Heavy	
Hair Belting	Light		4	Yes	No	No	Yes	Good	Good	Good	Good	Fair	Poor	Good	Light	Absorbs shocks, has high elasticity, pliability; excellent for outdoor drives or in acid or gritty conditions.
	Lt. double		6	Yes	No	No	Yes	Good	Good	Good	Good	Fair	Poor	Good	Medium	
	Double		8	Yes	No	No	Yes	Good	Good	Good	Good	Fair	Poor	Good	Heavy	
Balata Belting	3 and 4 ply		4	Yes	Yes	No	Yes	Poor	Good	Good	Good	Poor	Poor	To 110° F.	Light	Is practically stretchless, and the toughness and waterproof qualities of Balata Gum make for long wear.
	5, 6, and 8 ply		6–10–20	Yes	Yes	No	Yes	Poor	Good	Good	Good	Poor	Poor	To 110° F.	Medium	
	10 ply		30	Yes	Yes	No	Yes	Poor	Good	Good	Good	Poor	Poor	To 110° F.	Heavy	
Solid Woven Cotton Impregnated Belt	Single		4	Yes	Yes	No	Yes	Good	Good	Good	Good	Poor	Poor	Fair	Light	Efficient and economical on high-speed spindle drives, because of high frictional qualities.
	Double		8	Yes	Yes	No	Yes	Good	Good	Good	Good	Poor	Poor	Fair	Medium	
	Heavy d'ble		12	Yes	Yes	No	Yes	Good	Good	Good	Good	Poor	Poor	Fair	Heavy	

type is of heavier construction than the split flat box, and is suitable for slow speed shafting at almost any load. Grease lubrication is preferable.

Self-Oiling Rigid Pillow Blocks are similar to the preceding type, except in the highly important matter of lubrication. They are equipped with an oil reservoir sufficient for about a month's normal operation. This type has a substantial bearing surface, heavy structure, positive lubrication, and saves both lubricant and maintenance costs over the earlier types. Up to 110 r.p.m. lubrication should be by ring, chain or collar; above this speed, the capillary system is preferable.

This type bearing should be used on the average head shaft, when supported from floor, concrete foundation, or wall. A two-bearing shaft permits using a plain base plate under the pillow block; but when more than two bearings are required, an adjustable base plate should be used. A two-bearing head shaft may be supported from a wall, with this bearing, by means of wall brackets, but it should not be used for a wall-supported line shaft.

The Angle Self-Oiling Rigid Pillow Block has all the characteristics of the preceding type, except that it is split at an angle of approximately 45 deg., instead of horizontally. It is intended for use where a severe pull would be exerted directly against the cap of the horizontal type, and permits better distribution of such a load.

The Turned-Liner Rigid Pillow Block is a more rigid and rugged version of the rigid pillow block; the bearing body having three or four ridges concentrically bored, to receive turned recesses on the babbitt-receiving portion, resulting in extreme rigidity of assembly. This type is for use in immediate proximity to gearing or heavily loaded pulleys, or in any case where extreme rigidity of shafting is important.

The Ball-and-Socket Self-Oiling Pillow Block is one of the most serviceable types of pillow block for all around use on long head shafts or on line shafts. It is rugged, has all the good features of the preceding types, and can adjust itself to shaft movement. It is vertically adjustable, and is made in sizes from $1\frac{7}{16}$ to $4\frac{15}{16}$ in. shaft diameter.

The Spherical Ball-and-Socket Pillow Block has all the characteristics of the preceding type, except that it has no provision for vertical adjustment. It is used for moderately high speeds, because of its stability.

The Adjustable Ball-and-Socket Drop Hanger is primarily intended for supporting line shafting, but can be used on lightly loaded short head shafts and on jack or counter shafts which must be hung from above. Inverted, it can be used as a floor hanger. It has both horizontal and vertical adjustment, and permits the bearing to adapt itself to irregularities of shaft movement.

The Four-Point-Suspension Type Drop Hanger permits both vertical and horizontal bearing adjustment, but holds the bearing more rigidly than the ball-and-socket type. The latter is more generally used on heavily loaded line shafts.

The Heavy Head-Shaft Ball-and-Socket Drop Hanger is designed to meet the need for supporting heavy-duty head shafting from overhead instead of from substantial foundations. Equipped with self-oiling bearings, it is of massive construction, permits adjustment and can be depended on for severe service.

The Adjustable Ball-and-Socket Post Hanger is designed for head and line shafting that must be supported from steel or wooden columns. Its clearance is not sufficient to permit its use as a wall hanger unless the pulleys are of extremely small diameter. Its design permits adjustment, and the bearing can adapt itself to inequalities of shaft movement.

The Adjustable Ball-and-Socket Wall Hanger is intended for supporting light head shafting or line shafting from a wall, where a clearance of from 12 to 18 in. is required. It is of light construction and should not be employed for shafting of more than $2\frac{7}{16}$ in. diameter. For larger sizes, the cast iron wall bracket, equipped with ball-and-socket pillow block, should be used.

The Wall Box is intended for use as a bearing support where shafting passes through a wall. The brickwork or concrete is built around the box, the top of which is arched to provide support for the upper wall.

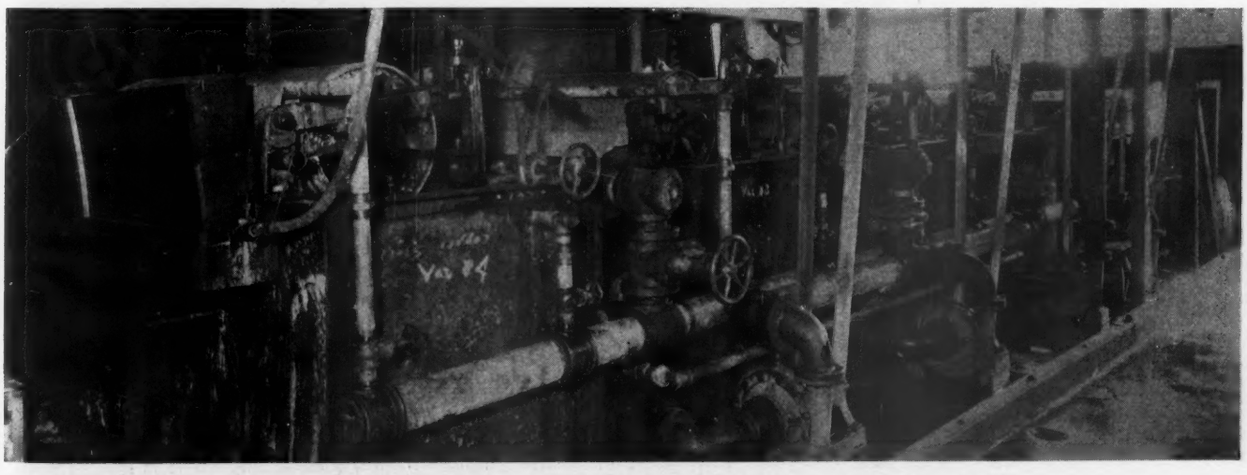
The Cast-Iron Sling Hanger provides an excellent support for line, counter or jack shafting under heavy bending or vibration stress. For strength, no other type can compare. Both horizontal and vertical adjustment of the bearing are provided for. This type is especially suitable for support of shafting next to gears.

The Plain Babbitted Hanger Bearing is preferable to the self-oiling type on certain applications where excessive grit and dust interfere with proper operation of the latter. This is true, for example, in saw mills, on conveying work where the material is dusty or gritty. Grease lubrication best meets the need of such service.

The Ring-Oiling Babbitted Hanger Bearing is extensively employed for line, jack and countershaft work, because it affords an efficient means of carrying the oil to the bearing surfaces. At speeds above 125 to 140 r.p.m., however, the ring creates a churning action which tends to carry sediment from the bottom of oil reservoir to the bearing surfaces.

The Capillary-Oiling Babbitted Hanger Bearing is similar to the ring oiling type, except that it is equipped with two soft wooden blocks provided with alternate saw cuts, which are held against the shaft by springs. Capillary action carries the clean lubricant to the bearing surfaces. This type is best employed at speeds above 125 to 140 r.p.m.

The Flexible-Steel-Roller Hanger Bearing is of cast iron, split, equipped with two sets of rollers, and is made in sizes from $1\frac{7}{16}$ to 3 in. shaft diameter. It will fit the standard hanger frames, size for size. For sizes above 3 in., and for the $1\frac{15}{16}$ and $2\frac{15}{16}$ in. sizes, the ball-and-socket type roller bearing box should be used. This is a splendid anti-friction bearing for general line-shaft work, and is easy to apply because of its split design.



THIS VIEW, in one of the plants of the American Writing Paper Company, is typical of difficult drive conditions. A special type of belting is required here.

The Flexible Steel Roller Ball-and-Socket Pillow Block has all the desirable anti-friction qualities of the hanger bearing, but has a housing which permits it to conform to shaft irregularities when used as a pillow block. It is made in sizes up to and including 5⅛ in. shaft diameter and is adaptable to all uses where ball-and-socket babbitted bearings are employed.

The Solid Steel Roller Hanger Bearing employs hardened and ground solid steel rollers held in position by a cage. The rollers do not contact the shaft itself, but operate on a steel bushing which clamps on the shaft. The elements of the entire assembly are split, making application easy. This type is made in sizes up to 6 in. shaft diameter and will fit any hanger frame, size for size.

The Tapered-Steel-Roller Hanger Bearing is a radical departure in design from both of the types of bearings described above. Like the flexible-steel-roller, it has been developed for industrial power shafting after a long and successful service in the automotive field. This bearing is solid and rugged and its design provides for the handling of both radial and thrust loads, an advantage not possessed by the other two types of roller bearings. It is not split, and must be slipped over the end of the shaft. It is made to fit the standard hanger sizes.

The Tapered-Steel-Roller Ball-and-Socket Pillow Block has all the desirable characteristics of the bearing just described, but is mounted in a rugged two-piece housing with an internal machined spherical seat. It is, therefore, self-sligning. This is an efficient anti-friction pillow block for heavy duty on head shafts, as well as on line and jack shafts.

The Ball-Bearing Hanger Bearing is made in a number of different styles and makes. Like the roller bearing, the ball bearing has won its way in the industrial power transmission field by sheer merit. Ball bearing hanger boxes are not split, and must be slipped over the end of the shaft. They are available in sizes up to 6 in. shaft diameter, and fit standard hangers, size for size. Ball bearings, because of their design, handle thrust as well as radial loads.

The Ball-Bearing Ball-and-Socket Pillow Block has the same design raceways and ball-and-cage assembly as the hanger bearing, but the ball-and-socket mounting accommodates it to shaft motion where the latter is out of true alignment. This type has all the desirable features of the previously described hanger bearing, and should be used on line shafting supported from walls or from concrete or wood supports.

The Ball-Bearing Rigid Pillow Block is small, compact, and extremely serviceable for line and head shaft support. It is rigid only in the sense that it cannot be adjusted vertically without the aid of base-plate adjusting wedges. The ball bearings, however, permit it to be adjusted horizontally.

The Bronze-and-Graphite Oilless Bearing is constructed of high-grade phosphor bronze, cast with symmetrical grooves which are packed under hydraulic pressure with a special hard lubricating graphite. There is sufficient graphite lubricant in each bearing to outlast the bearing itself, as the wear is uniform on the bronze and graphite surfaces. Such bearings have a wide field of use on machinery of certain types, and on lightly loaded line shaft, countershaft, and loose pulley work, because of their comparative economy.

Hardwood Lubricant-Impregnated Oilless Bearings were originally an accidental discovery; the result of using hardwood bearings when metal was scarce, and resorting to profuse lubrication. The modern version of this type is made of seasoned hardwood thoroughly impregnated with a lubricant which outlasts the bushing itself. Its cleanliness has made a particular place for it in the cotton and textile industries.

Metaline Oilless Bearings are made of either phosphor or gun-metal bronze, with inserted plugs of metaline. The latter is composed of metallic oxides and other substances reduced to an impalpable powder and molded in steel molds; the resulting plugs being inserted into drilled holes in the bronze bearing. The dry lubricant produces a smooth polish which improves with use. This type bearing is applicable in a wide variety of conditions, similar to the two types previously described.

Power Transmission Clutches

The Toggle and Wood-Friction-Block Clutch is made both in solid and in split types; the former in from 4 to 16 in. outside diameter, the latter in sizes from 10 to 72 in. outside diameter. This clutch has strong friction grip, obtained from the end-grain of maple blocks driven into the outside disk, contacting the inside driving plate through toggle mechanism. This style clutch is suitable for light or heavy loads, at low or high speeds, and its simple design permits ready adjustment.

The Lined Disk and Self-Oiling Sleeve Clutch employs a radically new system of rolling leverage. Three pairs of one-arm toggles are arranged to roll radially outward on convex tool-steel plates. This form of toggle gives low leverage and a large friction plate clearance at the point of disengagement. The sleeves of this type are made for either grease lubrication or ring oiling; the former for speeds up to 150 r.p.m., and the latter for speeds above that. This is an efficient and serviceable type of clutch for low powers.

High Speed Clutches are made solid, because at high speeds the split type would not be as safe. There are several types available, of various makes. One type employs disks, under spring tension; the disks being of bronze. Each size of this type is designed to use from two to six bronze disks; the lesser number being employed for small power and moderate speeds, while at high speeds it is advisable to use a small clutch with a larger number of disks, to minimize the centrifugal force.

The Worm-and-Gear-Controlled Clutch utilizes an entirely different clutch mechanism from any of those just described. The friction elements are a series of hardwood or asbestos blocks. The disks are of cast iron, and are drawn against the friction blocks by worm-threaded studs operated by spiral gears, in turn rotated by racks attached to the sliding collar. The design provides for long life without maintenance attention, and the sleeve can be had plain-reamed, bronze-bushed, ball-bearing bore, or flexible-steel-roller bore. The plain sleeve should not be used above 250 r.p.m., the bronze bushed sleeve should only be used at low and intermediate speeds, while above 800 r.p.m. it is advisable to employ anti-friction bearings. A feature of this type clutch is that it can pick up the load gradually and smoothly, without jerk.

The Friction Pick-Up and Positive Lock Clutch provides a means of picking up a load by clutch action, and then locking the members by pins as soon as speed is attained. Once locked, there is no further possibility of clutch slip, as the members are securely held by the pins. This type prevents slippage under shock loads, and obviates the possible hazard of sparks or heat in conditions where inflammable vapors are present.

The Coil-Spring Clutch is a departure from the usual industrial clutch mechanism. It has been designed especially to meet the need for frequent starting and stopping of heavy, high-power units. The largest unit of this type in operation at this writing handles 8,000 hp. at 50 r.p.m., but there is no reasonable limit to the size that can be built. It consists of a drum, forming the driving member; the coil and plate; the driven member, and a means of control. The large end of the high-carbon-steel coil is permanently attached to the plate forming the driven member. The small end of the coil is free, when the clutch is disengaged. To engage it, a lever causes the free end of the coil to contact the driving drum and gradually tighten around it until both members become practically an integral unit. This type affords a delicacy of control particularly adapted for haulage, rolling mills, etc., where heavy loads must be picked up without shock.

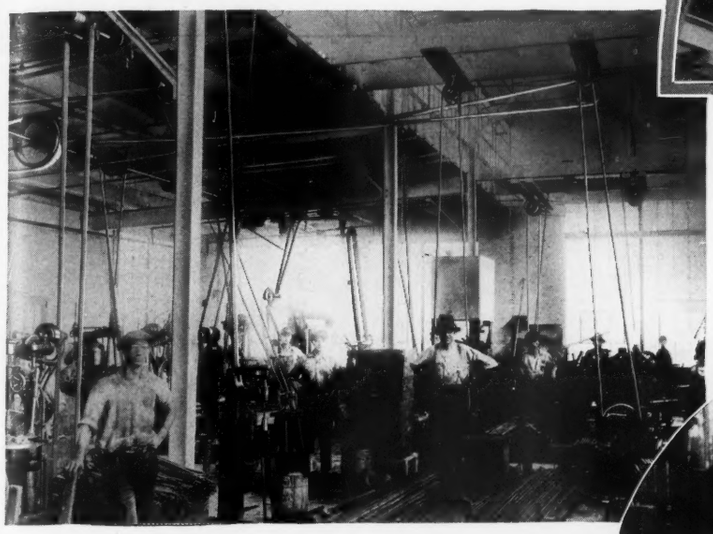
Friction Cut-Off Clutches are similar to regular friction clutches, except for the absence of a sleeve. They are intended chiefly for connecting together two lengths of shafting so that one may be started or stopped while the other is operating. They are made in a number of different styles, split and solid, by various manufacturers.

Jaw Clutches provide a simple and convenient means for connecting and disconnecting a load, where shock is inconsequental, and speed is low. These clutches should not be used on speeds

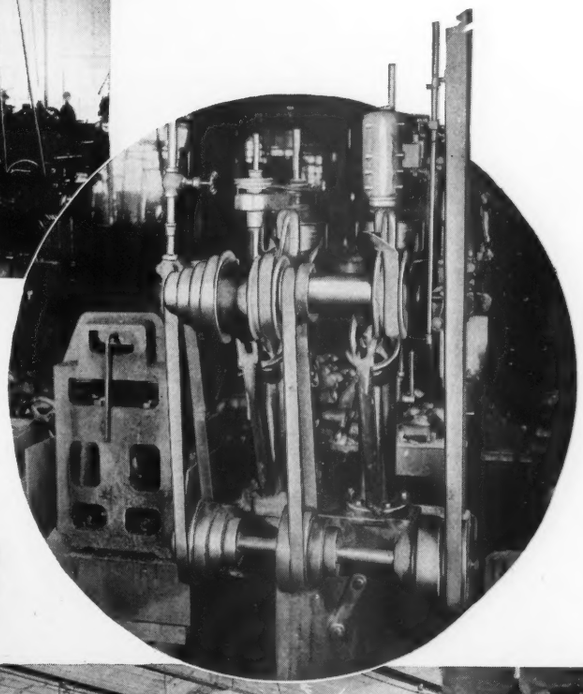
(Please turn to Page 567)

Some Rights and WRONGS *of Mechanical Power Transmission*

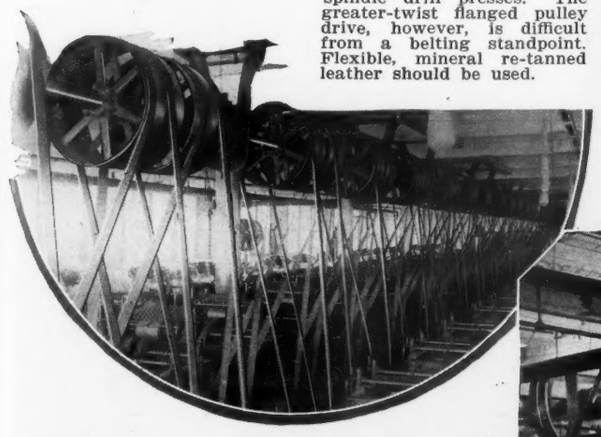
GOOD MOTORS, hangers, pulleys and belts are only part of the problem. In this case, bearings are badly located, imposing undue strain on the shaft.



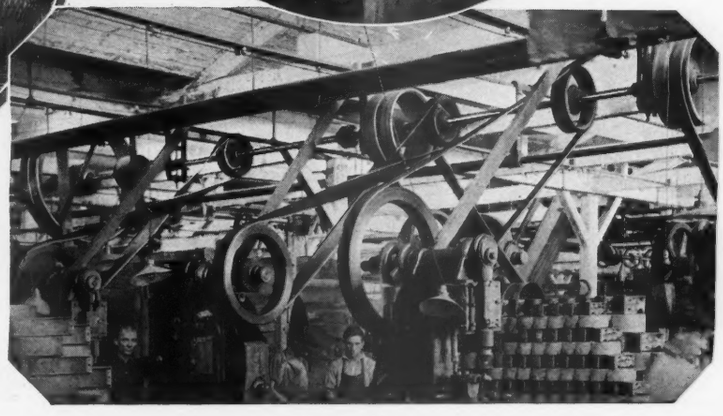
NOTE the excessively long, crossed drive, overhead. A belt, here, is bound to weave and whip, constituting a dangerous hazard and materially shortening belt life. A countershaft should be used in such cases as this.



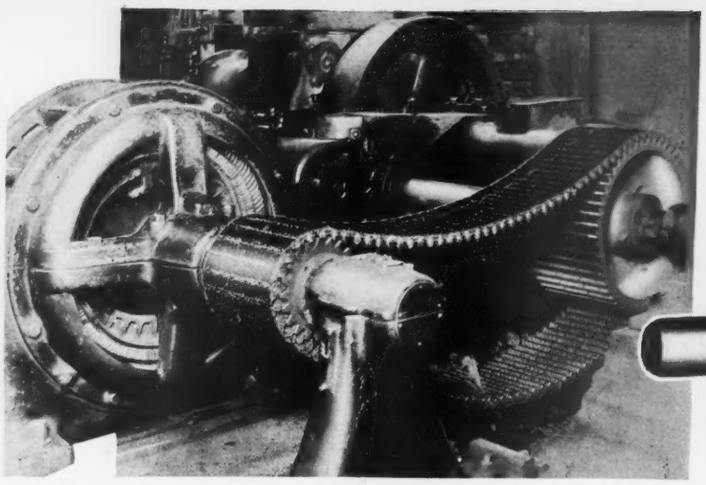
THIS is accepted machine tool practice on multiple spindle drill presses. The greater-twist flanged pulley drive, however, is difficult from a belting standpoint. Flexible, mineral re-tanned leather should be used.



AN EXAMPLE of a lineshaft installation carrying too heavy a burden. A splitting up into groups would help, at least, to reduce the excessive friction load.

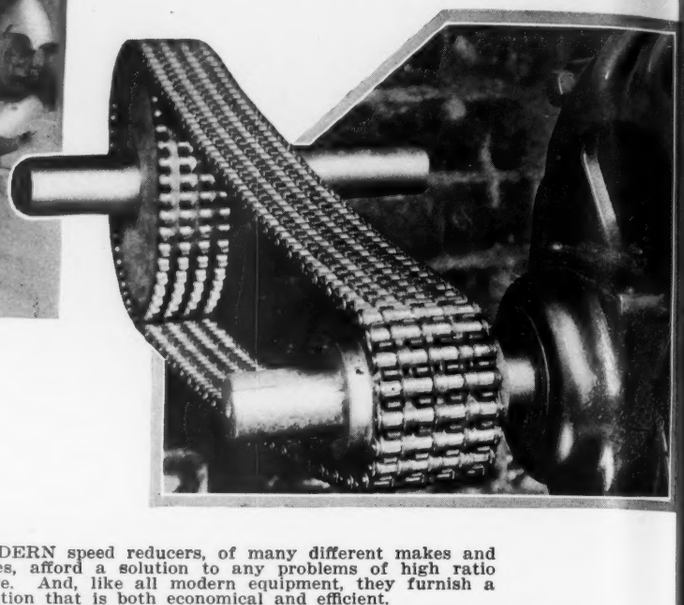


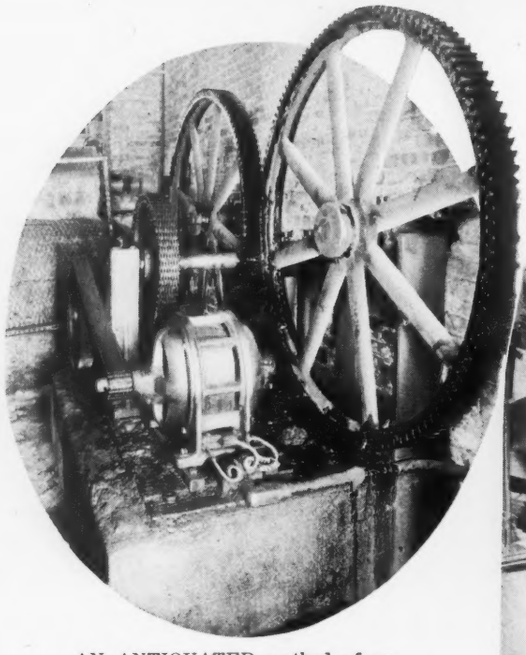
HERE is an example of a good lineshaft layout, with bearing hangers placed where the strain will be properly supported.



HERE is another type of silent chain drive, showing how the problem of heavy drives on short centers may be efficiently solved.

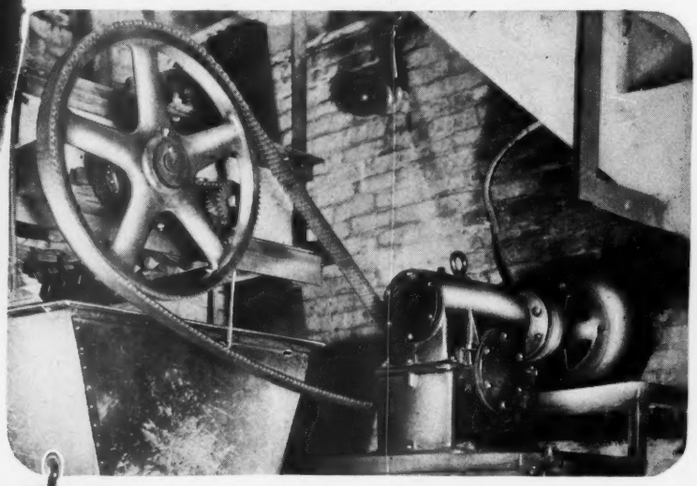
STILL another short center application; this time, a roller chain. Considering all the different efficient means available, there is no excuse for the drive shown at the right.

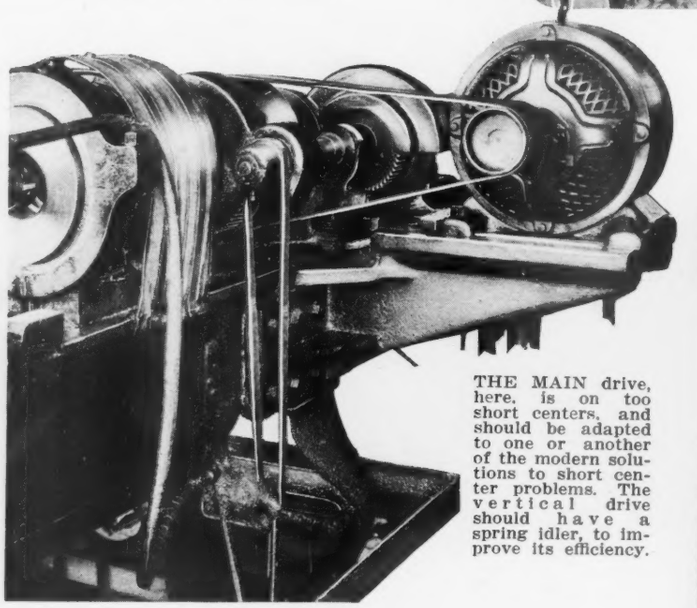




AN ANTIQUATED method of securing a 250 to 1 reduction. Contrast this with the modern method shown in the adjacent view.

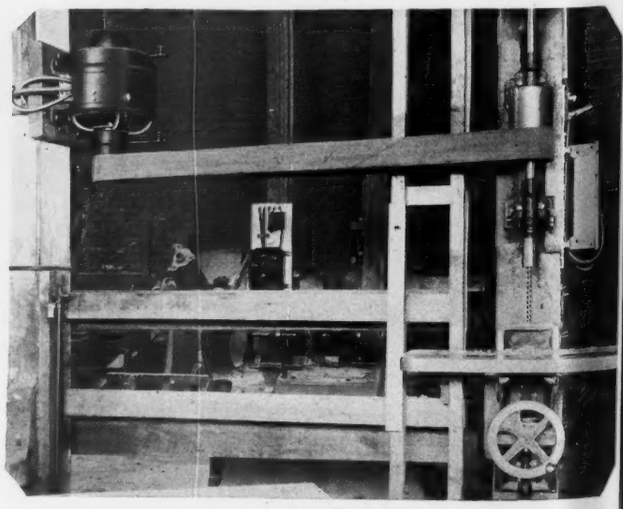
MODERN speed reducers, of many different makes and types, afford a solution to any problems of high ratio drive. And, like all modern equipment, they furnish a solution that is both economical and efficient.

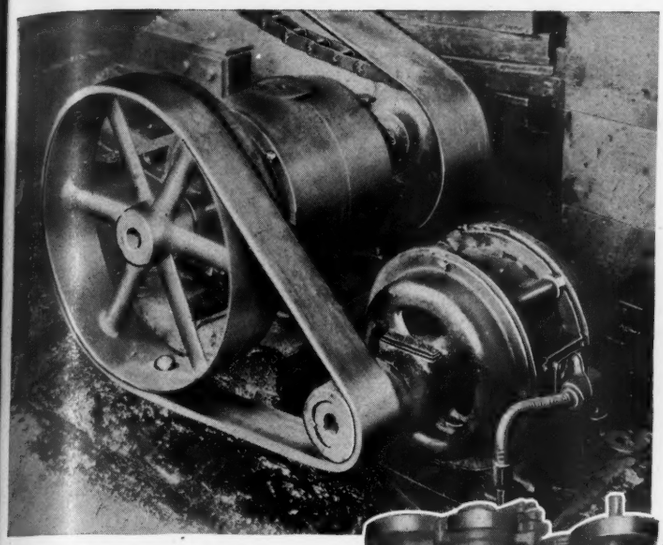




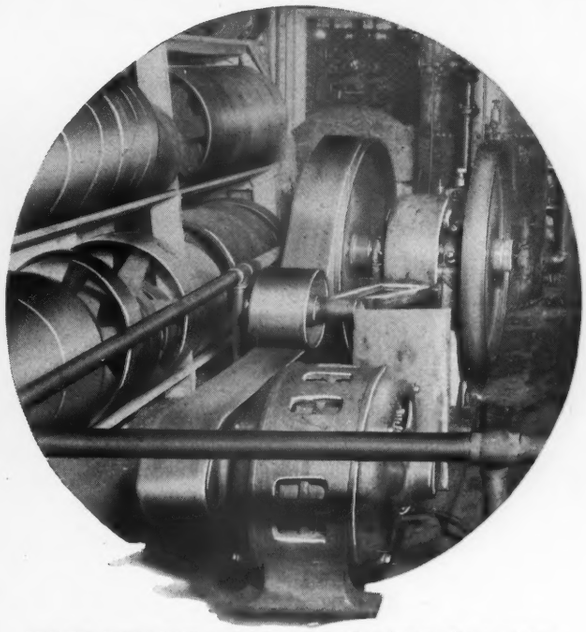
THE MAIN drive, here, is on too short centers, and should be adapted to one or another of the modern solutions to short center problems. The vertical drive should have a spring idler, to improve its efficiency.

QUESTION—What keeps this belt from dropping, of its own weight? Answer — excessive belt tension. Flanged pulleys should be used in such a case as this.

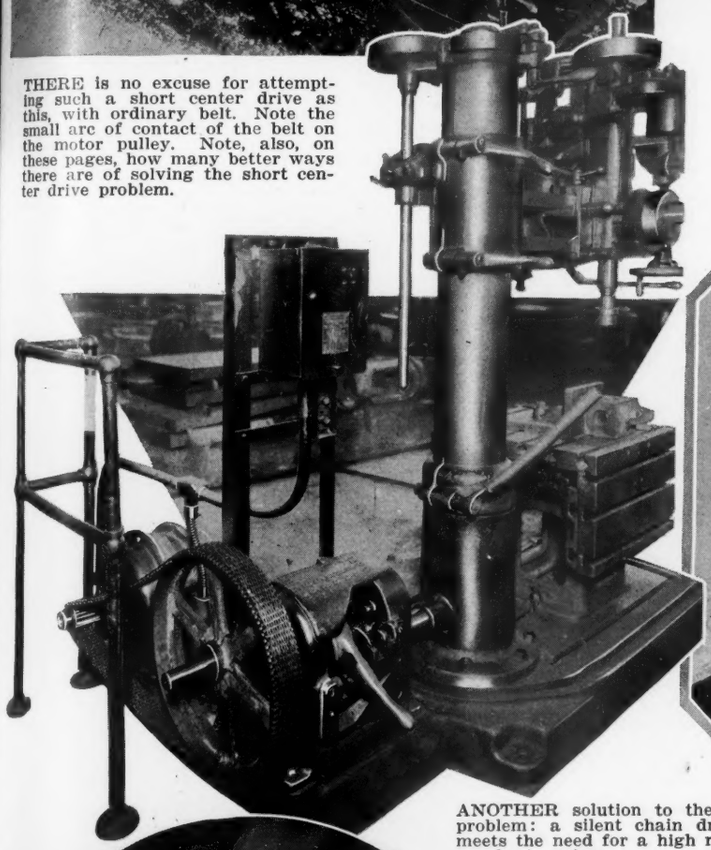




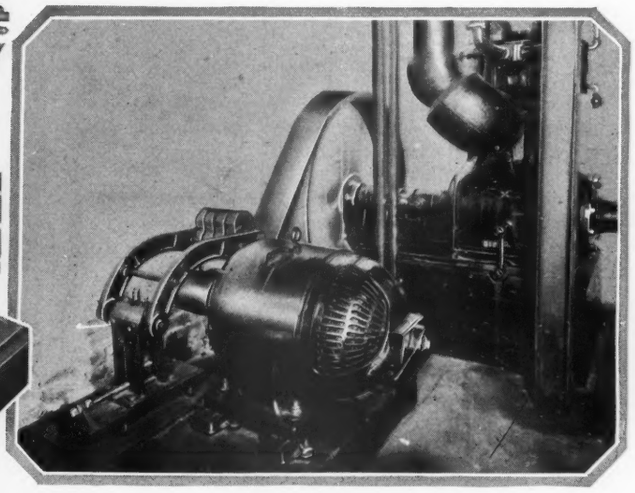
THERE is no excuse for attempting such a short center drive as this, with ordinary belt. Note the small arc of contact of the belt on the motor pulley. Note, also, on these pages, how many better ways there are of solving the short center drive problem.



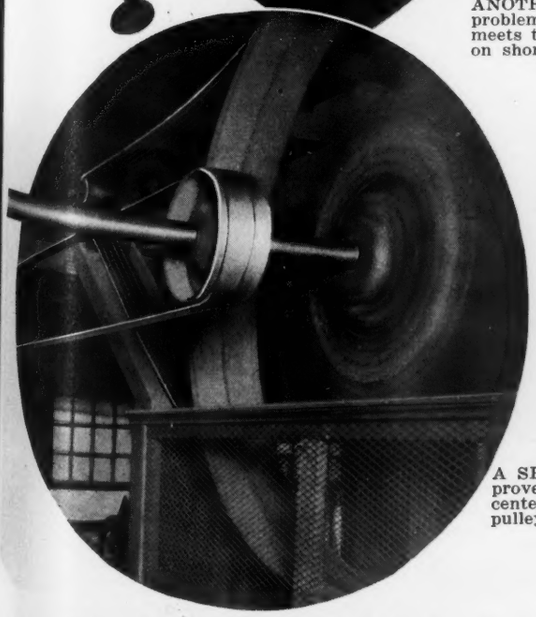
IDLER PULLEYS are a means of solving short center drive difficulties—but not when installed as this one is. It should have been placed so as to increase the arc of belt contact on the drive pulley.



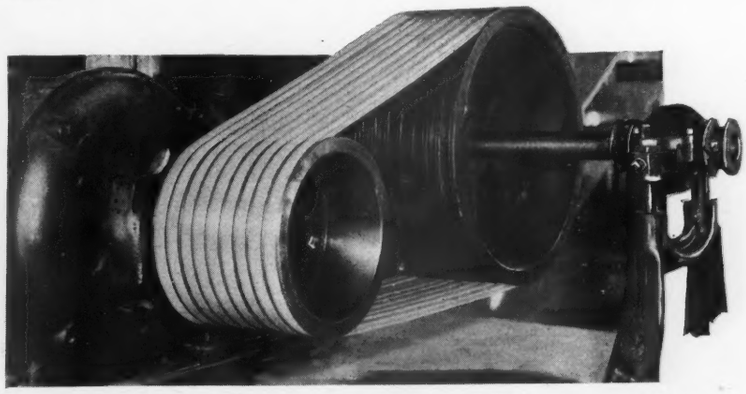
ANOTHER solution to the short center problem: a silent chain drive. Also, it meets the need for a high ratio reduction on short centers.



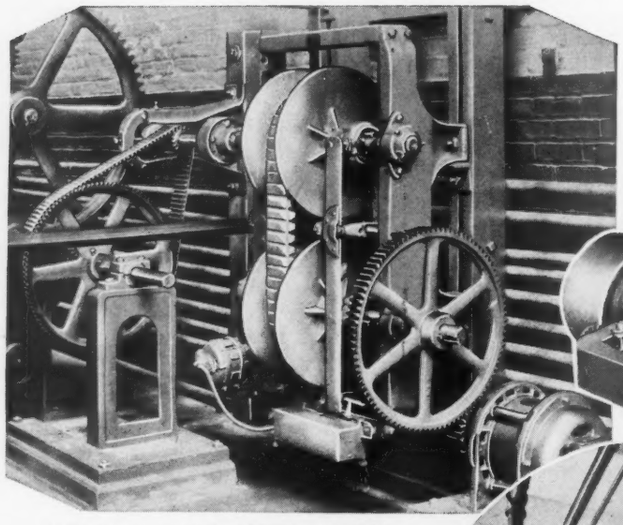
HERE is a scientifically placed idler pulley, so designed as to wrap the belt more firmly upon the drive pulley as the load increases.



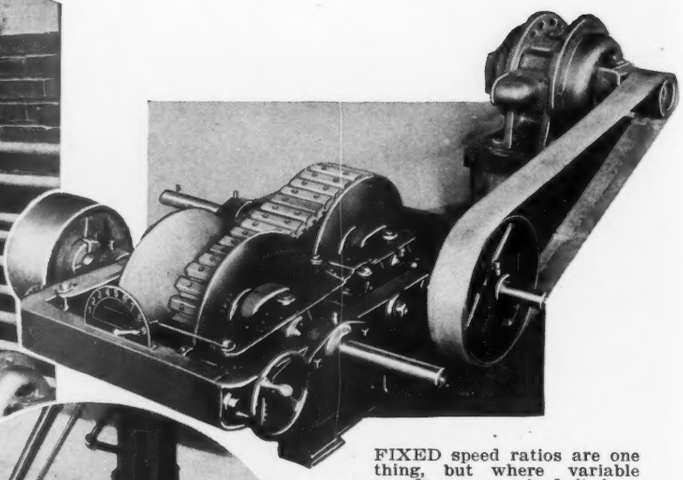
A SPECIAL TYPE of belt which has proven successful on high ratio, short center drives using ordinary flat pulleys.



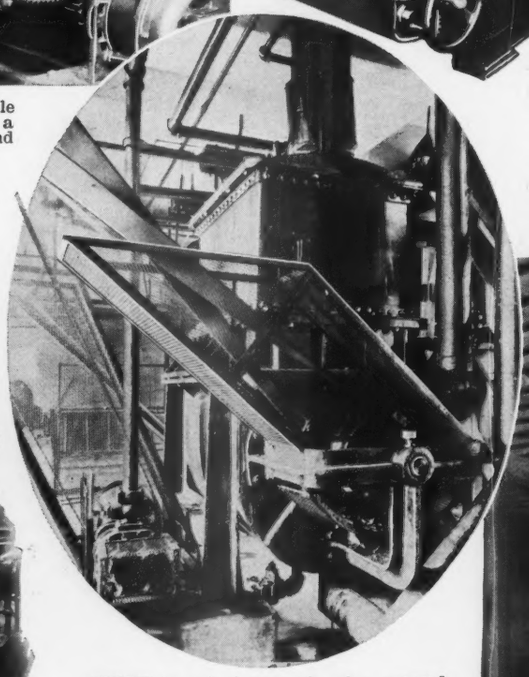
A SPECIAL V-SHAPE endless belt, running on grooved pulleys, provides a short center belt drive without slip. This is another highly successful solution.



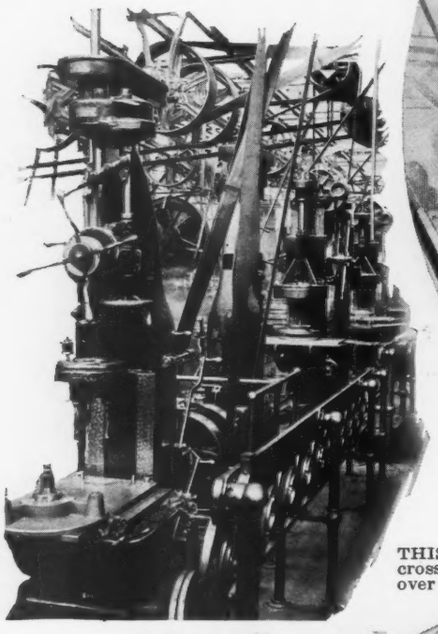
ANOTHER SUCCESSFUL variable speed device; in this case, showing a vertical installation, gear driven, and in turn driving through silent chain.



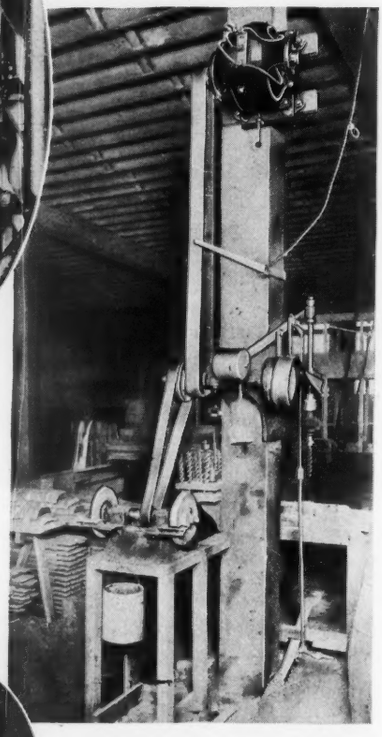
FIXED speed ratios are one thing, but where variable speeds are required it is a simple matter to obtain them, with high efficiency, without resorting to variable speed motors. This shows a horizontal installation, belt driven, of a widely used and successful variable speed transmission.



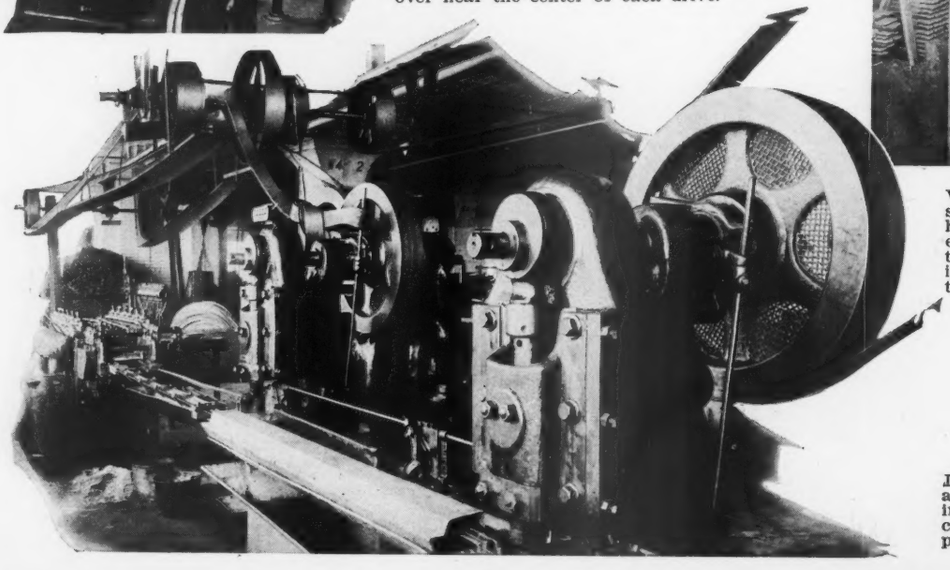
HERE is a bad example of a crossed belt drive. The belt is too wide to be crossed successfully, and its interference at the crossover wastes power.



THIS SHOWS two properly applied crossed belt drives, with the crossover near the center of each drive.



VERTICAL drive could (and should) have been avoided here, because of its low efficiency. Also, note how the quarter-twist drive is improperly lined-up, causing the belt to ride off the pulley.



DANGEROUS practice—to let a belt ride a live shaft when not in use. The belt should be held clear of the shaft by a belt perch.

A Step Forward in the Interest of "Service to Production"

INDUSTRIAL ENGINEERING has been pledged to industry's newest division, which is composed of those groups and those individuals that render Service to Production in maintaining regular operation.

In the theater, without its service group—scene shifters, curtain raisers, electricians, property people, wardrobe managers, headed by the stage manager—the play cannot go on. In industry, without that division which controls electrical and mechanical services and plant maintenance—production would stand still.

As the boon of mechanization grows, more and more necessary become the men and the departments rendering that service to production which insures the uninterrupted flow of industry's products.

Foreseeing the key position of this new division of industry, the McGraw-Hill Publishing Company has anticipated its publication needs by building *Industrial Engineering*. The present publication is the result of a series of consolidations, each of which charted a definite change in industry's problems of Service to Production.

Begun in 1882 as *Review of the Telephone and Telegraph*, which shortly became *Electrical Review*, the publication served the electrical industry, and continued to do so after it had absorbed *Western Electrician* and *Electrical Engineering* in 1918.

In 1921 *Electrical Review* was purchased by the McGraw-Hill Publishing Company, and the scope of its service was expanded to cover a large part of its present field. The name was accordingly changed to *Electrical Review* and *Industrial Engineer*, which later became *Industrial Engineer* and then *Industrial Engineering*.

In December, 1927, *Industry Illustrated* was consolidated with *Industrial Engineering* under the ownership of the McGraw-Shaw Company, now a division of the McGraw-Hill Publishing Company, Incorporated.

During the past year readers have noticed a broadening of the field of *Industrial Engineering*, which now serves the electrical, mechanical, and plant maintenance departments. Their function of insuring uninterrupted production under correct plant conditions is a big job, and deserves the guidance that a carefully planned, well-rounded industrial publication under positive leadership, can furnish.

Blank & Stoller, N. Y.

L. C. MORROW
Editor of Industrial Engineering

With this issue *Industrial Engineering* renews its pledge to make available that guidance, and introduces to its readers L. C. Morrow, who becomes its editor-in-chief. Mr. Morrow comes to *Industrial Engineering* directly from another of the McGraw-Hill publications, the *American Machinist*, and brings with him a background of wide practical experience in industry as well as in the publishing field. He is a graduate of the College of Engineering of the University of Cincinnati, class of 1912. Prior to his eight years as managing editor of the *American Machinist* Mr. Morrow's connections in industry were so fortunately selected that his work took him into all departments—he has spent quite as much time "behind the scenes" as on production.

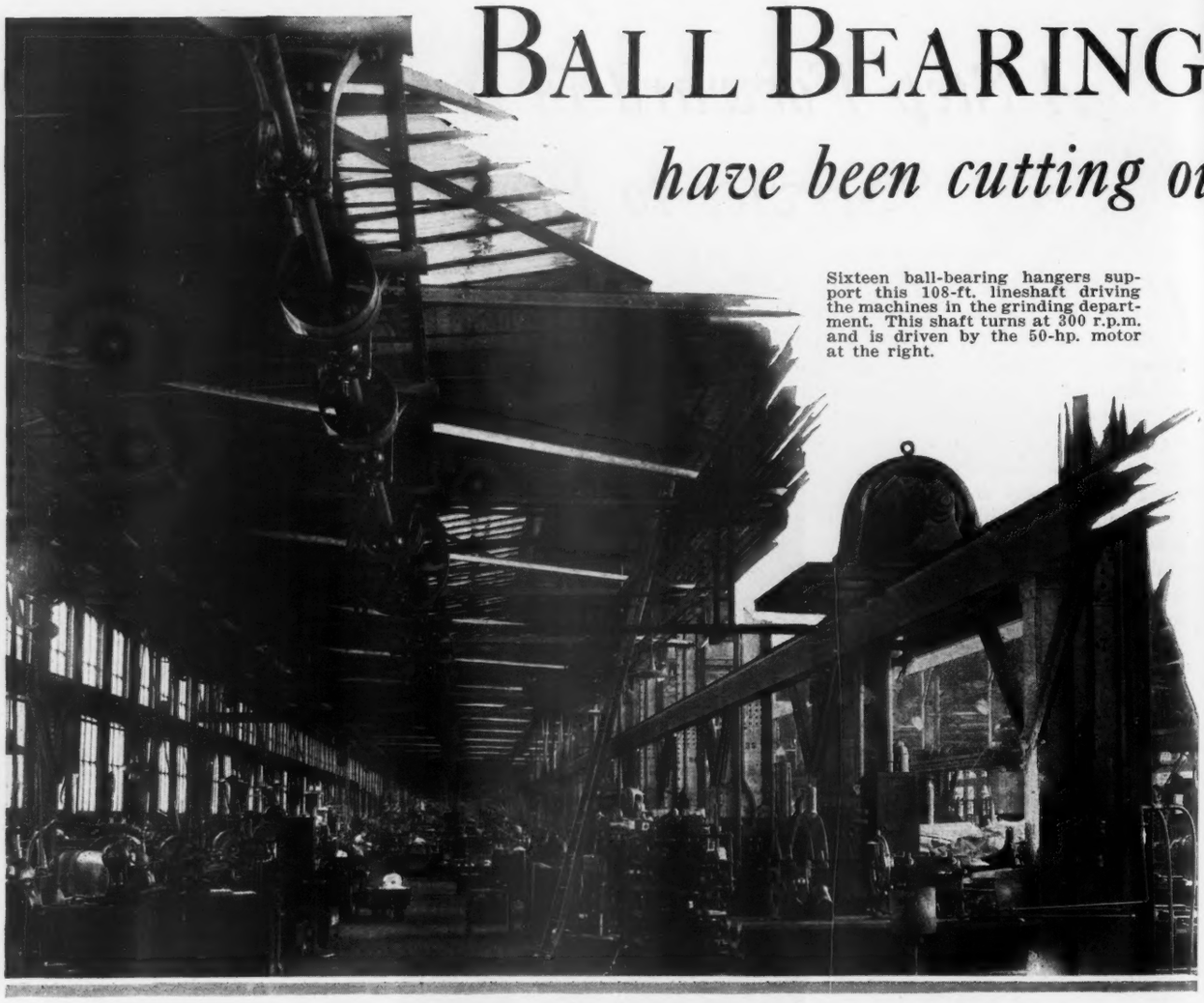
During several years' service in the U. S. Ordnance Department and with the British Ministry of Munitions, his work brought him into contact with the activities of twenty or more important industrial plants. Previous to his war work, Mr. Morrow was connected with the Lodge & Shipley Machine Tool Company, the Barney & Smith Car Company, the Laidlaw-Dunn-Gordon Company, and others.

During the past three years he has been a member of the executive committee of the Machine Shop Practice Division of the American Society of Mechanical Engineers, serving for two years as chairman of the division, a position he now holds. He is also a member of the American Society for Steel Treating. It is expected that his association activities will continue, as heretofore.

Conscious of the publisher's responsibility for leadership and authority, this new appointment is made in the firm belief that it will bring to *Industrial Engineering* a combination of practical plant experience and editorial technique that will result in a great step forward in the interest of Service to Production.

James H. McGraw

BALL BEARINGS *have been cutting our*



Sixteen ball-bearing hangers support this 108-ft. lineshaft driving the machines in the grinding department. This shaft turns at 300 r.p.m. and is driven by the 50-hp. motor at the right.

EVERY user of power wants to utilize the power that he pays for just as efficiently and with as little waste as possible. Waste of power means waste of money. A further objective in good plant operation is reduction of maintenance through the installation of equipment that will keep running and give dependable service with the minimum amount of attention. These are the chief considerations that led us to install ball bearings on all of our main lineshafts and on many of our jack- and countershafts about ten years ago. During these ten years we have learned some things about ball bearings that may be helpful to other plant men.

We are engaged in the manufacture of lathes of all types and for present purposes our plant may be considered as being divided into the following departments: (1) lathe; (2) milling and gear cutting; (3) drill press and screw cutting; (4) special, containing special types of lathes and screw machines; (5) grinding; (6) tool making and tool grinding.

With the exception of a small number of large machine tools, and some high-speed grinding equipment, all of our shop equipment is group driven from long lineshafts, which run through the center of the bay or department, the production machines being placed in two long rows on each side of the lineshaft. The necessary speed reduction and control are obtained through jack- and countershafts mounted above the production machines.

THERE IS little room for argument over the advantages that antifriction bearings offer in the way of reducing power losses and cutting maintenance costs. But how long may they be expected to give trouble-free service on lineshafts, for example? How much and what kind of care is needed in order for them to give the best service of which they are capable? The answers to these and other important questions will be found in this article.

Much, but not all, of this auxiliary equipment is fitted with ball bearings. Some of it is old, some of special type furnished by the manufacturers of the equipment it drives, and some of it operates under conditions that would make the use of ball bearings hardly worth the expense of putting them in. All of the main lineshaft bearings are of SKF manufacture. On the jack- and countershafts we have some Gurney and Fafnir bearings, in addition to the SKF type.

Taking up some of the departments in more detail, the main lineshaft in the lathe department is 125 ft. long,

ON LINESHAFTS OPERATING COSTS *for 10 years*

By F. SCHOEFFLER
Superintendent, The Lodge & Shipley Machine Tool Company, Cincinnati, Ohio

$2\frac{15}{16}$ in. in diameter, and is driven at one end by a 50-hp. motor through a $2\frac{15}{16}$-in. jackshaft that is connected to it by a 12-in. belt. This jackshaft is equipped with Fafnir bearings. In passing, it may be mentioned that this arrangement is not entirely ideal, but it was made necessary by conditions that need not be discussed here, and has served satisfactorily. In all of our other departments the driving motor is located at about the center of the lineshaft. This arrangement tends, of course, to reduce the stresses on the shaft.

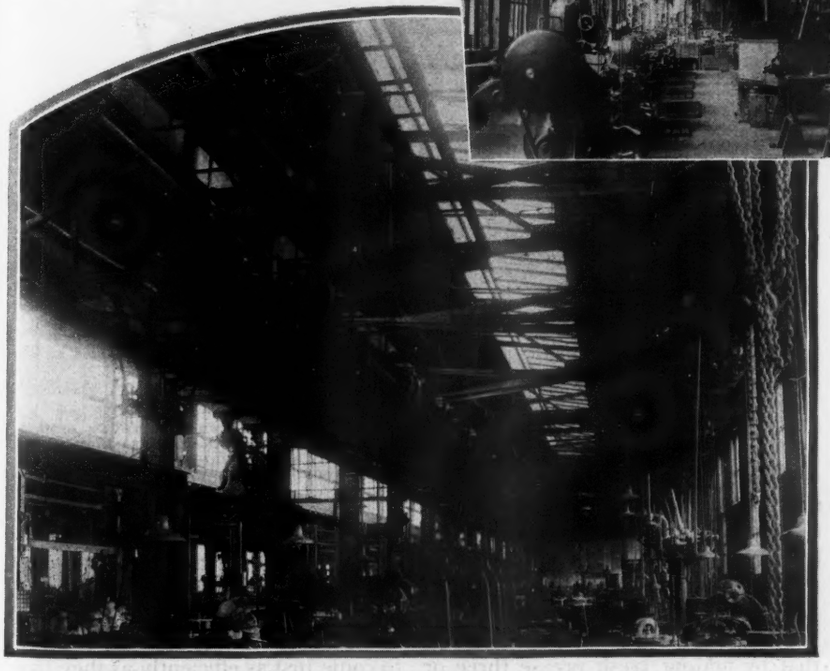
The main lineshaft in the lathe department is supported by SKF adjustable hangers, spaced on 8-ft. centers, and drives a number of shorter lineshafts ranging from 12 to 30 ft. in length, and countershafts on each side of it. This lineshaft turns at 250 r.p.m.

The machines in the milling and gear cutting department are driven in similar fashion by a $2\frac{15}{16}$-in. main lineshaft that is also approximately 125 ft. long and turns at 150 r.p.m. There are 20 bearings on this lineshaft. About half of the jack- and countershafts in this department are also equipped with ball bearings.

The arrangement of the equipment in the other departments mentioned at the beginning of this article is essentially the same as in those that have been described before. The chief difference is in the length of the lineshaft and the speed of operation. Thus, in the grinding department the lineshaft is 108 ft. long, and turns at 300 r.p.m. In the drill press and screw cutting department, the lineshaft is 125 ft. long and is driven at a somewhat higher speed — about 450 r.p.m.

The main lineshaft in the tool making and tool grinding department is 108 ft. long and turns at approximately 250 r.p.m.

THIS IS THE TOOL ROOM. A 108-ft. lineshaft supported on sixteen ball bearings drives the machines in this department. The 50-hp. motor driving the shaft had to be mounted on the floor and is protected by the sheet-iron inclosure that can be seen in the center.



LOOKING EAST in the drill press department. This lineshaft is 125 ft. long and turns at 450 r.p.m. on nineteen ball bearings.

* * * *

In all cases the lineshaft hangers are mounted on wooden footings which are in turn bolted to 8-in. channel irons that are supported on edge by the heavy steel roof trusses. This method of mounting the hangers leaves little to be desired from the standpoint of strength, rigidity, and accessibility in case it becomes necessary to make any changes in location

or layout of the lineshafts or the machines themselves.

Regardless, however, of how strong or solid a support may be, a certain amount of settling or warping is almost certain to take place in time. On the other hand, proper alignment of shafts is a matter of too great importance to be overlooked or left to chance. Therefore, we go over all of our lineshafts once a year and make whatever adjustments are necessary on the hangers. We have found the

IN THE MILLING and gear-cutting department many of the countershafts, as well as the main lineshaft, are mounted on ball bearings.

* * * *

use of a transit to be the most convenient and accurate means of checking the correctness of the alignment of our shafts.

The method of using this instrument is simple enough, and consists briefly in setting up the transit at one end of the shaft and sighting through it at a colored target that is suspended by a hook placed over the other end of the lineshaft at a suitable height above the floor.

With this level established it is a simple matter to suspend the target from the lineshaft, beside each hanger in turn, and note any differences in the level. We usually find that a few hangers are slightly out of line, but it does not take long to make the necessary adjustment. Then we have the satisfaction of knowing that no abnormal stresses are being placed on the bearings through poor alignment of the shaft. Poor alignment is not only wasteful of power, but frequently leads to bearing trouble.

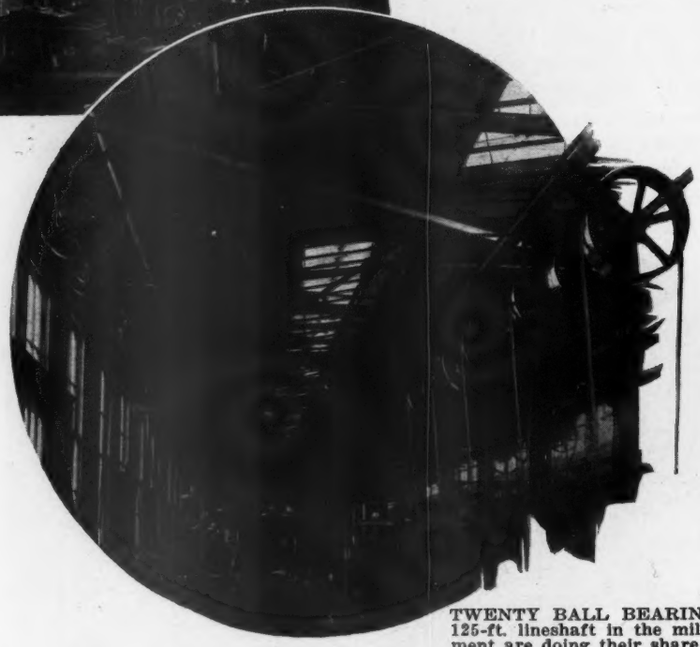
As soon as possible after the first of the year it is also our practice to remove the cover from all of our ball bearings, wash them out with kerosene, wipe them dry and repack them with heavy grease. It takes a force of three or four men about a month to go over all of our ball bearings, inasmuch as this work can be done only on Saturday afternoon when the shop is not working. However, this is the only attention that they receive during the year and is not a high price to pay for the service that they have been giving us.

We have recently equipped six hanger bearings with Alemite fittings for pressure lubrication, in the hope that by adding fresh grease three or four times a year, it will not be necessary to wash the bearings out and repack them with fresh grease, as we are now doing.

Doubtless the care that we take of our bearings has been reflected in the excellent service that we have obtained from them, for they have given us no trouble. Out of a total of about 200 ball bearings, of which about 150 are on our main lineshafts, only one or two have had to be replaced during the ten years or so that most of them have been in service, and I am not at all sure that these failures can be blamed entirely on weaknesses or defects in the bearings.

Inasmuch as we did not run any load tests when these ball bearings were installed, we do not know how much power they are saving, but no doubt it is a considerable amount. The same thing is true of the maintenance attention required; we do not know how many men would be needed to take care of all these bearings if they were of the ordinary babbitted type, and conditions have changed so much from what they were when these ball bearings were installed, that it would be idle to try to draw any comparisons.

We do know, by actual experience, however, that the majority of our lineshaft bearings have given upwards



TWENTY BALL BEARINGS on this 125-ft. lineshaft in the milling department are doing their share in reducing power and maintenance costs to the minimum.

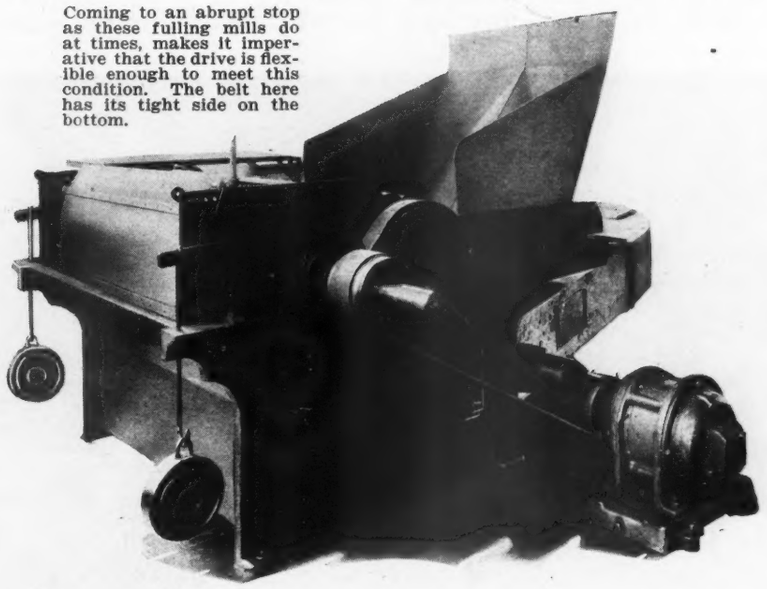
* * * *

of 10 years of dependable service, at a low cost for maintenance attention, and so far as we can tell they will continue to serve us for a long time to come just as efficiently as they have in the past.

Study your SHORT-CENTER DRIVE *Requirements*

It pays . . . says

By A. A. CUSHMAN
Consulting Engineer
The Felters Company, Millbury, Mass.



Coming to an abrupt stop as these fulling mills do at times, makes it imperative that the drive is flexible enough to meet this condition. The belt here has its tight side on the bottom.

WE HAVE given an unusual amount of attention and study to power transmission in our plants, that is, to drives which are called upon to meet more or less unusual conditions due to the nature of our processes and machinery. Perhaps, the way in which we operate has something to do with it.

Our material goes through in certain lengths so production must be based upon runs of felt, instead of on a time basis. In other words, we cannot shut down whenever we please, or at more or less frequent intervals. A run is wasted if it is not completed. Consequently it must be started over again. This means that it is imperative that we keep our machines running.

To indicate what this means to us, we employ no direct-connected units in our plant. Every drive is hooked up with a belt or chain, or the variable-speed, herringbone-gear drive is used, simply because, we cannot afford long shut downs for motor repairs. We have standardized on motor sizes wherever possible, so we are prepared to take out a motor and substitute another quickly.

At any rate, we have made a special and serious study of drives to fit our needs and have found that the time and thought given to planning for each drive well worth all it has involved. We have been able to do things with drives that we did not think possible; to increase production efficiency and decrease lost time, and to effect other very important advantages, simply through this desire of ours to apply the one best drive to fit each case and not attempt to fit the machine to the drive.

This has not meant that we have standardized on one type of drive for all services. In fact, in a plant such as ours with such a wide variety of transmission conditions and requirements, such standardization would seem impossible. We use open-belt drives where they best fit the particular requirements; we use chain drives where they seem to fill the bill better than any other type; and we use gear drives when they are best suited.

For many of our problems, however, there appeared to be no drive that had all of the needed requirements. We had reached a point where we were experimenting with the design of a balanced-idler type of drive to meet these conditions when the Pulmax drive came to our attention. It seemed to us to have the qualities as regards design, mechanical improvements, etc., that we had been seeking. A tension governing device which has many features of adjustability to insure satisfactory performance appealed to us rather than the short-center feature, which to us in many instances is relatively unimportant.

An example of the conditions these drives had to meet is that of our fulling mills which are of the pusher type. In our Millbury plant, these have eight so-called hammers, each of which give a constantly recurring impact. This impact as you can imagine, develops an exceedingly difficult driving condition, particularly when the hammers time up together as they are apt to do. Then you get a surge which works back to the motor if an inflexible type of drive is used.

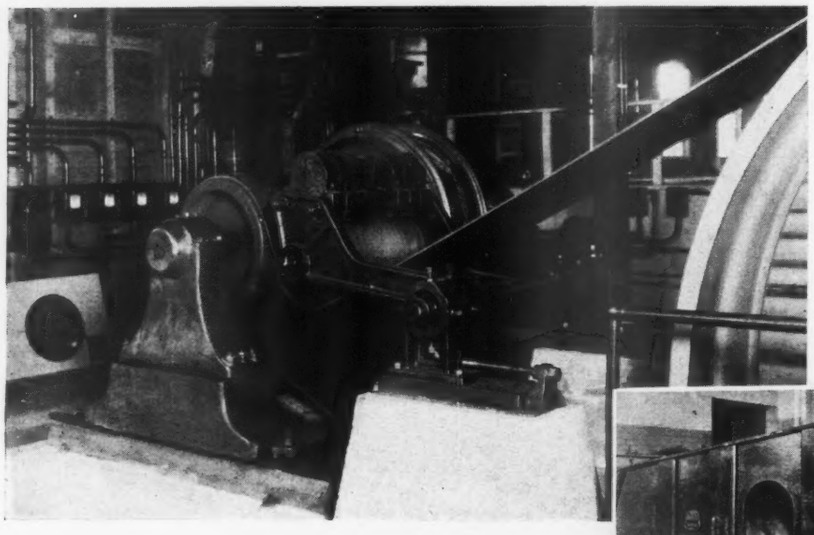
Previously, we employed multiple-belt reductions and were constantly tightening the belts, but with the Pulmax we obtained sufficient flexibility to take care of the shock without straining the motor and we were able to use a single belt. We are now running these fulling mills without shutdowns and without giving the drives anything like the attention that we had previously given them. Three of these 25-hp. drives are on our eight hammer fulling mills at Millbury and

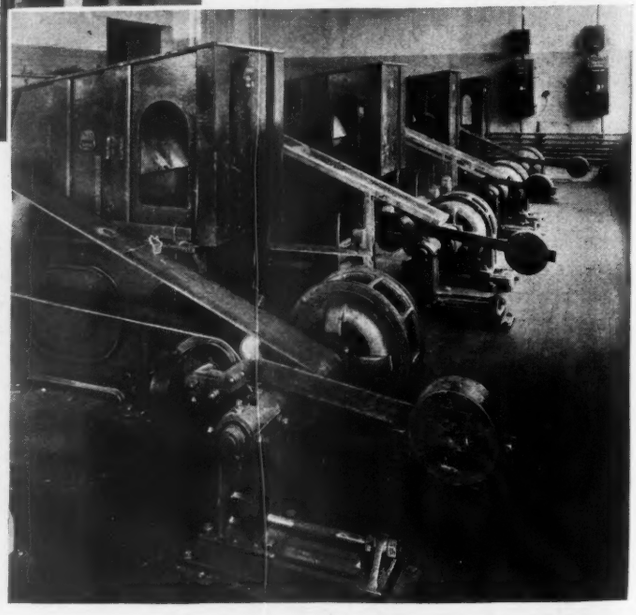
we are putting in nine with special wide-face pulleys to operate on 5-ft. centers at our Johnson City plants. We will also have four on the main lineshafts to the fulling mills, thereby making it possible to reduce belt width and save us some valuable space.

Our rag pickers constitute an interesting drive problem. These machines sometimes get clogged which means an abrupt stop, and again we have the problem of a drive flexible enough to meet these conditions. Here again, the Pulmax drive fitted them because they happened to fit the particular job in each case better than any other type of drive that we know about. If these drives are carefully adjusted when put in they will operate steadily and continuously with very little attention or maintenance. The low tension which they make possible means long service from belting and we find that the life of these drives compares favorably with that of any other type of drive. In addition, they have given us the advantages of adaptability to driving conditions that we could not obtain without ing to another. In place of this we have the Pulmax drive with which we have obtained a very compact installation.

To sum up, we have had unusual success with the short-center belt drive having the adjustable features, but by no means do we recommend this as a panacea for all transmission difficulties. As stated at the beginning of this article, we have developed a very definite policy of selecting drives to meet the particular driving conditions. It so happens that in our case the Pulmax drive did meet these conditions, which have resulted in worth while advantages to us. The point we would like to make is that the selection of drives is worthy of any engineer's critical attention. The conditions and requirements for a given drive should be analyzed and then each type of drive considered for the given case to see how well it meets all of the conditions.

In some cases, it will be one type of drive, in other cases, another. Judging by our own experience, it is likely that the short-center, governed-ten-





A SPACE problem solved with the Pulmax drive unit made it possible to put an office in the same building. The distance between pulley centers is 12 ft.

* * * *

CONTINUOUS operation is maintained with this battery of rag pickers regardless of the sharp load variation.

into the requirements very nicely and with it we have been able to keep the pickers up to full production at all times. The disadvantages of running overhead which would have had to be done with the open-belt drive were eliminated, thereby making a considerable saving in the cost of the drive as compared with the rather long chain drives that we would have had to use otherwise. Now, we have six of these 25-hp. drives on our rag pickers, and the advantages of flexibility as regards making quick substitution of motors, if necessary, and of low tension which means a minimum of attention to the belts, have been very apparent.

Another example of the advantages of this type of drive is that of our blowers. A blower shutdown meant a plant shutdown, so the logical solution was this simple type of belt drive rather than a direct connection or chain.

All in all, we have thirty or forty of these drives on pickers, fulling mills, lumpers, blowers, hardeners, dusters and perhaps other machines, and as I stated heretofore we picked overloading other types of drives or putting them in over-size and giving them special attention.

No doubt, the advantages of short centers and of a freedom of choice in the selection of pulley ratios would be important to many mills. The improvement in layout and the saving of space has proved an advantage to us in many cases. For instance, one main drive for fulling mills using a 12-in. belt had four reductions with an open belt that ran from one building to another. In place of this we have the Pulmax drive with which we have obtained a very compact installation.

To sum up, we have had unusual success with the short-center belt drive having the adjustable features, but by no means do we recommend this as a panacea for all transmission difficulties. As stated at the beginning of this article, we have developed a very definite policy of selecting drives to meet the particular driving conditions. It so happens that in our case the Pulmax drive did meet these conditions, which have resulted in worth while advantages to us. The point we would like to make is that the selection of drives is worthy of any engineer's critical attention. The conditions and requirements for a given drive should be analyzed and then each type of drive considered for the given case to see how well it meets all of the conditions.

In some cases, it will be one type of drive, in other cases, another. Judging by our own experience, it is likely that the short-center, governed-tension, belt drive will prove effective in a great many instances where it may not have been given consideration. It has certain advantages which it will pay every engineer dealing with transmission to keep in mind, not only for tough drives or unusual cases, but wherever you need the flexibility of a belt without the slippage or lack of positiveness of an open-belt drive and with the advantages of short centers, high-pulley ratios and continuous dependability.

QUESTIONS
Asked and Answered
By Readers

HERE IS A PLACE where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience

How Would You Paint This Ceiling?

We are confronted with the task of painting the ceiling of our plant. It so happens that this ceiling is about 50 ft. from the floor, and supported by steel cross members with girders running longitudinally. We propose using the spray machine and would like some suggestions on the easiest and least expensive method of taking care of this work. Naturally, a scaffolding of some sort will be used. P. K. N.
Phila., Pa.

* * * *

Locking of Squirrel-Cage Rotors

I shall appreciate it if readers will answer the following questions for me. (1) What will cause a squirrel-cage rotor to lock or refuse to rotate when power is turned on? The motor in question was a three-phase design, and the bearings were in good shape. The trouble was not caused by single phasing, as tests at the motor terminals showed that all lines were alive. The rotor would not lock in all positions, but in other positions it would until it was turned by hand. (2) What happens when a slipring motor develops a ground in the rotor itself, or in the external rotor circuit. What effect will a ground on one of the starting resistors have on the starting characteristics of a slipring motor? C.L.K.
Chicago, Ill.

* * * *

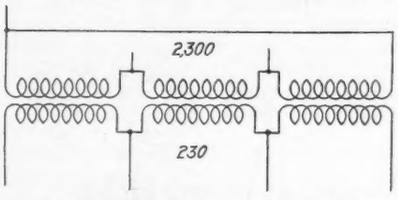
Exciter Loses Field Magnetism

Part of the power for driving our plant is furnished by a waterwheel, and part by a 50-hp. synchronous generator which is used to carry part of the load on the waterwheel during periods of low water. A Westinghouse Type SK, 3-kw., 125-volt, 24-amp., 1,700-r.p.m. exciter is belted to the generator. Several times during low water the exciter has lost its magnetism and failed completely. Low water does not affect the speed of either the generator or the exciter, nor is the generator loaded to capacity. On these occasions we have restored the fields by sending current from 125-volt d.c. lighting generator through them. Will some reader please tell me (1) what makes this exciter fail, (2) how we can prevent it, (3) the best method of restoring the field magnetism in case it does fail again.
Attawaugan, Conn. J.W.

* * * *

Use of Transformers on Different Frequency

In our plant there are three 500-kva. single-phase, 2,300/230-volt, 25-cycle power transformers connected delta-delta as shown in the accompanying illustration, and we wish to know if they



TRANSFORMER CONNECTIONS wanted for operation of 25-cycle transformers on a 60-cycle circuit.

will operate satisfactorily with the same connections on a 60-cycle circuit of the same voltage. If so, what will the regulation be at 80 per cent power factor on an inductive load of the same capacity as formerly existed at 25 cycles?
Cleveland, Ohio. J.M.

* * * *

Eliminating Trouble With Relay Plungers

Will some reader kindly explain the reason for the trouble I am having with inverse time limit relays? When making our semi-annual inspection I find our oil dashpots in which we use G. E. No. 21 oil, out of order. The plungers, after being in service a short time expand and by doing so will not rise when an overload comes on the motor. After putting the plungers in a lathe and using fine emery paper on them, they will work for a few months before the same trouble appears. By knowing what causes this trouble we can improve our operating conditions. C.E.K.
Lewiston, Maine

* * * *

Preventing Brush Marks on Collector Rings

One of the d.c. field collector rings on our three-phase, 375-kva. 440-volt alternator has several brush marks burned on its surface. Can any reader tell me how this can be prevented and what causes these marks to appear only on one ring?
Chicago, Ill. A.Z.

* * * *

Soldering Nichrome for Low-Resistance Joints

Will some reader tell me how to solder nichrome resistance wire, and how a joint or splice can be made whose resistance will be as low or lower than the rest of the coil or element?
Union, S. C. C.D.F.

* * * *

How Would You Start the Motor in This Case?

In our plant we have hand starting compensators on four similar 60-cycle, 600-volt, 150-hp. motor drives. So far, we have not had any trouble, neither do we anticipate any, but because we do not carry spare compensators I would like to have some reader tell me how one of these drives could be started in case the transformer inside a compensator should break down? Other readers probably have had experience along this line which might be of value to the rest of us. B. P.
New Bedford, Mass.

ANSWERS *Received to Questions Asked*

What Causes These Belts to Wabble?

We have several leather belts ranging from 4 to 8 in. in width that continually wabble across the faces of the pulleys in a way that is not only annoying, but makes me think that something is wrong. These belts are not overloaded and are running at moderate speeds. They appear to be in good condition, and I am unable to find the cause of the trouble. Can any reader tell me what would cause them to act in this way? Other belts operating under practically identical conditions do not show any tendency to wabble.
Philadelphia, Pa. P.E.K.

REPLYING to the question by P. E. K., page 461, in the September number of INDUSTRIAL ENGINEERING, either the pulleys are not properly mounted on the shaft or the belts are crooked, and it may be that the belts are not properly joined. Unless all joints are cut perfectly square and joined properly, the belts will not be straight.

P. E. K. does not state whether the belts are single or double. Single belts are more liable to take on an early wabble than are double belts because one edge of the single belt is usually weaker than the opposite edge. Double belts are more uniform in strength because each ply supplements the other.

W. F. SCHAPHORST.
Mechanical Engineer,
Newark, N. J.

Function of Kick Pin Jaws

In the article entitled "Laying Out and Making Pulled Coils," in the February, 1928, issue of *Industrial Engineering*, mention was made of kick pin jaws. Will someone please give me a more detailed explanation of how these are constructed and their function in making coils? W. B.
Victoria, Australia.

THE term kick pin jaw is derived from the fact that a fixture of some sort was found necessary to hold the wires at each diamond point of a coil that was being pulled to shape, and as this fixture had to slip over the ends of the coil a pin was necessary to prevent the coil from pulling out of the fixture. The ends of the coils had to be pushed up or down to clear the air gap, and as this is a separate operation it was called kicking the coil up or down. Inasmuch as one end of the fixture could be opened or closed, it was called a jaw; hence the complete fixture was termed a kick pin jaw.

The function of a kick pin jaw is to hold the wires at the diamond point from spreading apart or crossing, and at the same time give any desired shape to the diamond point or knuckle.

The shape of the diamond point is regulated by varying the distance between the center line of the pin and the center line of the radius used on the jaw proper. Thus by varying the distance *A* in Fig. 1, the shape of the loop can be changed.

Three different positions are shown in Fig. 2. At *1* the center line of the radius is on the center line of the pin; this will give the length of loop illustrated by *1*. At *2* the center line of the jaw radius is ¼ in. behind the center line of the pin. This will give a short loop, as shown at *2*. In the position at *3* the center line of the jaw radius is ¼ in. ahead of the center line of the pin; this will give a long loop.

Thus by changing the relation between the center lines, any combination

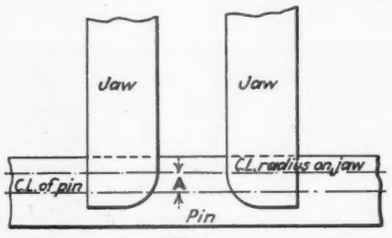


Fig. 1

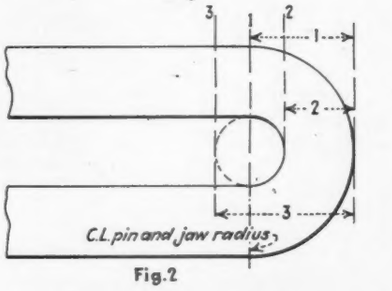


Fig. 2

THE SHAPE of the diamond point of a coil is changed by varying the distance between the center lines of the pin and the radius of the kick pin jaw.

can be obtained to meet the conditions, or the length of a given coil can be shortened or increased at will, a long loop being used on square or ribbon wire coils and coils designed for high-voltage operation. A. C. ROE.
Wilkinsburg, Pa.

Method of Filling Holes in Laminations

Will some one please tell me the best way to fill holes that are blown by grounds in the laminations of rotors and stators C.L.K.
Springfield, Ill.

IN answer to C.L.K., my method of taking care of holes in the laminations of rotors and stators is to remove the laminations and when placing them back stagger them around the circumference in such a way that no two spots will come together. To my mind this is the most effective way of repairing such a spot.

Any attempt to plug the hole will in all probability lead to some future trouble, especially when it is in a rotor, as magnetic stresses combined with centrifugal force would have a tendency to loosen any sort of plug inserted in the burned spot. W. T. E.
Ansonia, Conn.

What Is Causing Trouble With This Commutator?

We are having trouble with the brushes and commutator on a 125-kw. Crocker-Wheeler direct-connected generator installed a year ago. About once a week a black spot appears on the commutator, and the mica sticks up above the bars as though something were eating the copper away. I have turned the commutator down twice, and use a commutator stone each week to cut the mica down even with the bars, but this gives only temporary relief. I have also tried using vaseline on the commutator and boiling the brushes in Vaseline, as they chatter very badly at times anad wear rapidly. I shall be grateful for suggestions from readers as to how this trouble may be cured.
Kellys, Tex. E.R.

ANSWERING E.R.'s question, the fact that a black spot appears about every week, is an indication of a flat spot in the commutator, a reversed armature coil, or a partly carbonized mica segment. A generator will operate with a reversed coil in the armature, but this will cause arcing and blackening of certain commutator bars, depending on the number of circuits in the armature.

E.R. should turn his commutator round and undercut it with a three-cornered file, leaving a V-shaped slot. Then the carbon dust and other foreign material will have less chance to collect and cause trouble.

If this generator is not equipped with reaction type brush-holders, it will pay him to have them put on, as they will improve the operation of almost any machine. The old type brush-holders work fairly well until the springs become weak; then they are worthless. The reaction type brush-holder is in my opinion the only one to use where there is vibration in or around the machine. Vibration may be caused by worn-out bearings, shock loads, and so on. In the case of steam-driven generators, every time the drive shaft revolves it causes a slight jarring of the armature. This will cause black spots on commutators.

The use of Vaseline on the commutator will not be of permanent help. Furthermore, it is bad for the commutator.

Chattering may be caused by the brushes not being set at the proper angle, by worn-out brush-holders, by worn commutator, or by improper spring tension.

Commutator troubles are caused by so many different things that it is difficult to give any definite suggestions without seeing the machine operate. However, in addition to turning and undercutting the commutator, I would suggest that E.R. overhaul his machine carefully, checking up on the field coils, armature, commutator, bearings, spacing of brush-holders, type of brush-holders, and their condition, and believe that by so doing he will locate the cause of the trouble.

SAMUEL CARBAT.
Newark, N. J.

What to Use—and Where for Mechanical Power Transmission

(Continued from Page 554)

above 60 r.p.m. They may have either square jaws or spiral-type jaws; the former for infrequent shifting, the latter for more frequent operation.

Jaw Cut-Off Clutches occupy the same relationship to the regular jaw clutch as friction cut-off clutches do with respect to friction clutches. For very low speeds and under gritty, dusty conditions, they can be successfully employed for connecting power shafting.

Quills, or hollow shafts, are used instead of sleeves, where friction clutches are employed in connection with large pulleys, gears, sheaves, or sprockets, under heavy load. A quill is supported on its own bearings, relieving the shaft proper of all strain when the clutch is disengaged. Quills are usually of cast iron, though forged steel is employed where the service is exceptionally severe.

Collars and Couplings

Collars are made of cast iron, for general service, or of steel, for large diameter shafting with heavy thrusts. They may be had either solid or split, though the latter should be used wherever possible, as its location may be shifted with a minimum of trouble. Collars should be placed at each end of short shafts, next to the end bearings. On long line shafting, 50 to 75 ft., it is good practice to employ from four to six collars adjacent to the end and the intermediate bearings.

Flange Couplings are the most generally used, for connecting two adjacent ends of power shafting, because they are the most substantial type. They are made of steel or cast iron, for shafting from 1⅞ in. diameter upward, and with plain or male and female flanges. The latter tends to keep the shafts in truer alignment, but makes removal more difficult when occasion arises. The flanged type of coupling is generally employed on power transmission shafting 2⅞ in. and larger, and the halves of the coupling should be a pressed fit, keyed to the shafts, and then face-trued to assure perfect alignment.

Ribbed Couplings are made for use on shafting from 1⅞ to 6 in. diameter, and are especially adapted to sizes under 2⅞ in., and for quick erection of shafting. They are adaptable for general lineshaft work, in the smaller sizes, are keyed to the shaft, and may be had in split or solid design.

Sleeve Couplings are employed on shafting from ⅞ to 1⅛ in. diameter, under light load, where simple and rapid removal is a factor. They are made only in the solid type, and depend upon set-screws for shaft grip.

Universal Couplings are made in both single and double types, and permit coupling shafts at an angle not greater than 15 deg. for the single, and not greater than 30 deg. for the double. Speeds should be well below 300 r.p.m., and the greater the required angle, the slower should be the speed, to avoid excessive power waste.

Compression Couplings are used where a dust-proof coupling is a necessity, and on light service only. There are no recesses or projections, and the bolts are thoroughly protected; a tapered sleeve, drawn onto a split, tapered bushing by means of bolts, clamping the coupling to the ends of shafts.

Flexible Couplings are a result of the undisputed fact that it is impossible to maintain perfect alignment of the shafts of two machines, and that rigid couplings in such cases would be bound to cause trouble and loss of power. There are many makes and designs of flexible couplings, making use of a variety of different principles, from the extremely simple to the highly complicated. Selection is chiefly a matter of choice, based upon speed, load, power and space requirements, as well as a consideration of first cost and maintenance costs.

Power Transmitting Pulleys

Single-Belt Cast-Iron Pulleys are made in both solid and split types, are either keyed or set-screwed to the shaft (depending on power requirements) and are balanced to operate at speeds up to 300 r.p.m. They come in single-arm construction only, in sizes from 6-in. diameter by 3-in. face, to 48-in. diameter by 12-in. face. They are intended for use in connection with single or light double leather belting or its equivalent weight fabric or rubber belt, and it is inadvisable to employ them for belting of more than 8-in. width.

Cast-Iron Split Interchangeable Bushed Pulleys are keyless, and equipped with interchangeable split bushings to accommodate different shaft sizes. Made in sizes from 6-in. diameter by 3-in. face, to 54-in. diameter by 14-in. face, they are suitable for moderate power where single or light double leather belt, or its equivalent, is employed.

Double-Belt Cast-Iron Pulleys might be called the universal type of cast iron pulley, because their strength and general design permit their use for almost all average drive conditions. They are bored, key-seated and turned true, and are made in sizes from 3-in. diameter by 3-in. face, to 84-in. diameter by 30-in. face. Double-arm construction should always be employed in connection with heavy, wide belting.

Cast-Iron Tight and Loose Pulleys are extensively used throughout industry, as a ready means of starting and stopping machines driven from a line or countershaft. In their simplest form, they consist of a pair of pulleys of like diameter, one of which is keyed or set-screwed to the shaft, the other being bored to a running fit on the shaft and held close to the tight pulley by means of a collar. While simplest, this form is far from the best, as it involves con-

YOU HAVEN'T seen many examples of this kind of drive, unless you are familiar with the steel industry. The four belts on this finishing mill all go to the same drive pulley, one on top of the other.

stant trouble on the score of lubrication. It is this problem of lubrication that has given rise to a wide variety of designs of loose pulleys, by many different manufacturers. Bronze-bushed, grease lubricated loose pulleys are an improvement, as are the ring-oiling and the oilless bearing type. The loose pulley equipped with anti-friction bearings is undoubtedly the best solution, though high first cost has militated against their universal use.

The Pressed Steel Pulley has been used in industry for more than thirty year, and has kept pace, in improvements in design and materials, with the general industrial progress. There are a number of different makes and designs, each with its points of superiority. The steel pulley is from 30 to 50 per cent lighter than the cast-iron type, and can be safely operated at high rim speeds; 4,000 to 4,500 f.p.m. is common practice. The average make of steel pulley is furnished in sizes from 3-in. diameter by 3-in. face, to 120-in. diameter by 36-in. face. Made in split type, it is furnished with interchangeable bushings, permitting key, clamp or set-screw method of fastening to the shaft.

Tight and Loose Steel Pulleys fulfill the same functions as the cast-iron type, and manufacturers have met the requirements of this service by adapting the anti-friction bearing to the loose pulley.

Wooden Pulleys have the advantage of lightness, high frictional qualities and low cost, as well as the ability to absorb shock loads. They should not, however, be used where steam or excessive moisture is encountered. They can be had in any size required, the small sizes being made solid, and the larger sizes in split construction. There are a great many different varieties of wood-rim pulleys, some with wooden sipders, some with cast-iron spiders; others, again, being made of compressed wood fibers, rather than natural wood segments. All of these are excellent power transmitting mediums, and each has its particular advantages for certain classes of work. Properly to define the advantages and limitations of each type, would require a book in itself.

Paper or Composition Pulleys of various manufactures have won a place for themselves in competition with wood or metal, for certain classes of service, notably in the case of motor pulleys. For general transmission pulley work, the cast-iron, steel, and wood types rule the field in average practice, today; but this should not blind the transmission man's eyes to the distinct advantages offered by special types of pulleys for special service and conditions.

Miscellaneous Pulley Types are available, in addition to those classified under the preceding paragraphs. There are pulleys with perforated rims to dissipate the air cushion between belt and pulley, rims with friction wrapping, rims with friction inserts, etc. Each of these, too, has its special field of application. For average conditions, ordinary equipment meets all requirements, but there are difficult drives in many plants in almost every industry. Where these conditions exist, the higher cost of special equipment often proves a real economy because of the day-in and day-out savings in maintenance and in productive time.

Variable Speed Mechanism

Modern Mechanical Speed Transformers provide a compact, self-contained mechanical unit for receiving power at a constant speed and delivering it at any desired speed within the range of the particular unit employed. These units may be installed vertically or horizontally, and may be controlled manually, or can be equipped with remote control. They can be had in capacities from fractional horsepower up to 150 hp., and with speed ratios ranging from 2 to 1 up to 16 to 1. For exact and instantaneous speed variations, they provide a highly efficient mechanism whose functions cannot be performed by any other means.

Chain Drives

The Detachable Malleable Iron Chain was introduced in 1873, and has been widely used and consistently improved to keep pace with demands in its field. It is made in approximately 25 stock sizes. It is used in many outdoor applications, in certain saw-mill applications, and generally where speeds are under 400 f.p.m. and ratios not more than 5 to 1.

Steel Roller Chain resulted from the demand for a chain capable of carrying heavier loads, at higher speeds, and of greater accuracy of design. The light type is an accurately pitched chain of three times the tensile strength of malleable chain, and operates on the same cast-tooth sprockets as the latter. Its uses are the same, but its permissible speed is as high as 700 f.p.m. The heavy type is suitable for the same conditions as the light type, but is more rugged and capable of handling greater power.

The Finished Steel Roller Chain is intended for general power transmission purposes and is designed to operate on accurately cut sprockets. While higher in cost than the type just described, it can not only demonstrate its greater worth in similar applications, but it is applicable to a wider range of drive conditions. It can handle ratios as high as 10 to 1, and while speeds of 1,000 f.p.m. are possible, economy and long life dictate a speed of not more than 700 f.p.m.

Multiple-Strand Finished Steel Roller Chain is a development of the foregoing type, and provides a chain that has found successful application on drives from high speed motors. Maximum speed should not exceed 2,000 f.p.m. This type is available up to six strands in width, with a range in pitch of from $\frac{3}{8}$ to 2 in., and power capacities up to 150 hp. Its use is by no means limited to high speed motors, though its ability to handle high speed ratios makes it particularly suitable for such service.

Silent Chain represents a distinct class of power transmission chain, with practically unlimited speed capacities, and with an efficiency of approximately 98.5 per cent. It is an assembly of specially designed links which operate on cut-tooth wheels. There are several different designs, involving different linkage methods. Desirable speeds range from 1,200 to 1,500 f.p.m., though inclosed chains are successfully operated at higher speeds. Ratios may be as high as 15 to 1, though it is desirable to keep them between 1 to 1 and 7 to 1 if possible. Short centers impose no obstacle, though silent chain is by no means confined to short-center drive.

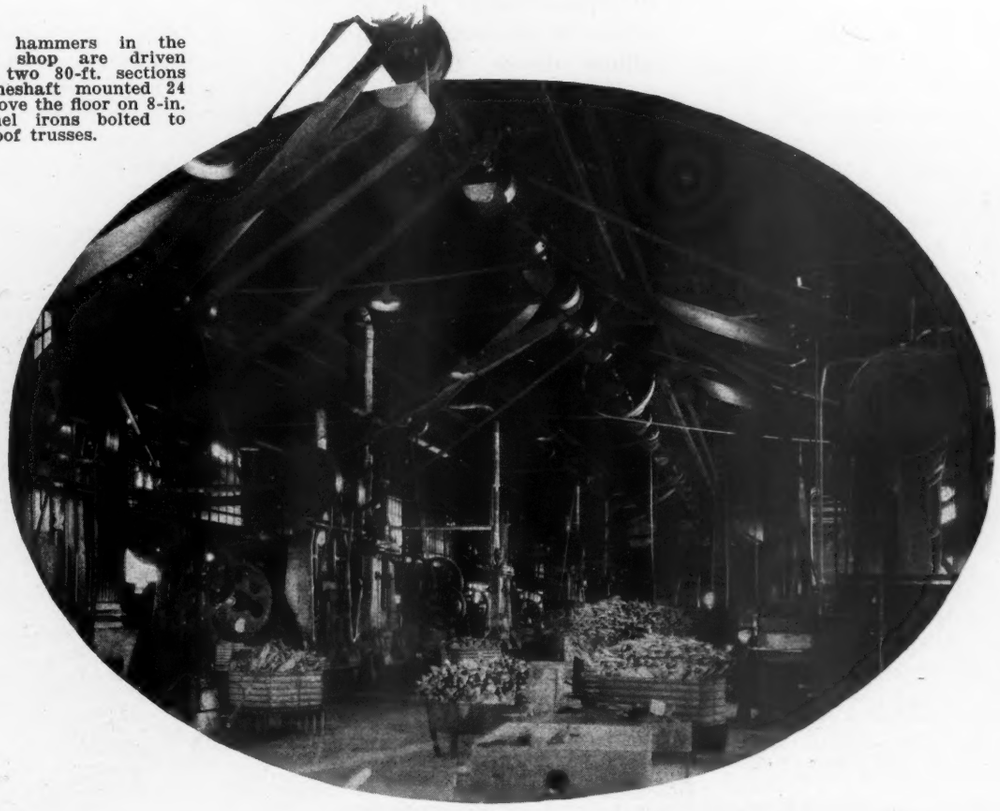
Speed Reduction Units

Modern Worm Gear Reducers have been perfected to such an extent as to overcome the disadvantages of early types and to dissipate the consequent prejudice against them. With scientifically designed gears and bearings, the better makes of this type reduction unit afford an efficient means of securing ratios of 60 or 70 to 1, while various adaptations of pinion or double worm gear can be made to multiply this. Above 70 to 1, the efficiency of a single worm reduction drops off, though the ratios available range from 3 to 1 up to 100 to 1. Double worm reduction affords a means, theoretically, of securing as high as 10,000 to 1; though torque considerations modify this considerably. It is common practice to couple motors of 1,800 or 1,200 or 900 r.p.m. to worm gear reducers at ratios of from $3\frac{1}{2}$ up to 100 to 1, involving powers from 1 to 250 hp.

Spur Gear Reducers have been developed to meet the requirement for higher ratios, where the efficiency of the worm gear begins to fall; at the same time, the spur gear is not limited to extreme high ratios, but is practical within the limits from 1 to 1 up to 500 to 1. While the worm gear results in a right-angle drive, the spur gear unit reduces in a straight line. Spur gear reducers are made in planetary and in non-planetary types; the former being capable of the higher ratio reduction, while the latter has the advantage, with low reduction ratios, of keeping rotational speeds at a minimum.

Herringbone Gear Reducers do not possess the right-angle feature of the worm gear, nor the shafts-in-line feature of the spur gear units. The high- and low-speed shafts of this type are parallel but offset. The single-reduction type herringbone unit is commonly manufactured for ratios up to 8 to 1, the double-reduction type up to about 60 to 1, and above that point triple reduction is resorted to. A recent modification makes use of spiral bevel gears for the first reduction, making this type applicable in place of the worm drive

LAYOUT *of* POWER DRIVES *in a* *Forging Plant*



Drop hammers in the forge shop are driven from two 80-ft. sections of lineshaft mounted 24 ft. above the floor on 8-in. channel irons bolted to the roof trusses.

By C. E. BRACKEN

Plant Engineer,
Steel Improvement and Forge Company,
Cleveland, Ohio

LAYING out the power drive in the new and larger plant into which we have recently moved, presented some interesting problems which were further complicated by the severe conditions under which a large part of our equipment operates. We make drop forgings of all kinds and the conditions in the forge shop, in particular, are comparable to those found in steel mills in that all of the equipment is subjected to heavy shock loads and fairly high temperatures, in addition to which it operates in the presence of unusual amounts of smoke and dust for 24 hours a day.

To begin with, all but a few of the machines in our plant are group driven. We consider that individual drive would not be desirable in view of the excess motor capacity that would be necessary if each machine, especially the drop hammers, were driven by a separate motor. Because of the fluctuating loads we feel that we could not hope to have anything like a satisfactory power factor, which is an item that we cannot afford to overlook. Today we are maintaining an average power factor of 85 per cent.

Electrical energy is brought into the plant at 220 volts, 60 cycles, three phase and distributed through a five-panel board to the five principal departments in the plant: tool room; forge shop; press room; power plant, in which we generate steam for the steam hammers, heating and other purposes; and the shipping department. In these departments we operate a total of 26 motors ranging in size from 150-hp. to ¼-hp. rating, with an aggregate rating of 900 hp. Included in this number are a few motors that drive the blowers and oil pumps for our heating and heat-treating furnaces, air compressors and other auxiliary equipment. With one exception all of these motors are controlled by ordinary compensators that are located convenient to the operator.

The motor referred to is a 150-hp. Allis-Chalmers synchronous motor with direct-connected exciter, that drives the first section of lineshaft in the forge shop. An automatic control board with two push button stations is provided for this motor. One of these stations is located on the control panel and the other is mounted in a convenient place in the forge shop. Use of this synchronous motor is what makes it possible for us to maintain a power factor of 85 per cent with a variable and fluctu-

ating load by regulating the exciting current on the field coils to such an extent as to have unity power factor at peak loads. At light loads it produces a good power factor and in this way corrects the plant power factor.

No particular trouble was encountered with the drives in the tool room. Here a number of lathes, planers, milling machines and similar equipment is driven from one $3\frac{7}{16}$-in. lineshaft 80 ft. long, the various machines being placed on each side of it and driven through countershafts. The main lineshaft is mounted on SKF ball-bearing hangers which are supported on two double rows of 5-in. channel irons placed back to back. These channel irons in turn are bolted to the 16-in. I-beams that support the roof. At a later date it is planned to add another story to this part of the shop building; hence, the use of such heavy beams. This lineshaft is driven by a 50-hp., 900-r.p.m. motor and turns at 230 r.p.m.

In the forge shop there are twenty belt-driven drop hammers and five steam hammers. The drop hammers are of several different sizes, the weight of the falling part ranging from 1,200 to 6,500 lb.

Each hammer is driven by two belts, but the sudden, severe stress to which the belts are subjected when the weight is raised can easily be imagined. It is a shock load of considerable magnitude.

All of the drop hammers are driven from two 80-ft. sections of $3\frac{15}{16}$-in. lineshaftings. What may be termed the first section is driven by the 150-hp. synchronous motor mentioned heretofore, with a 16-in. double belt which runs over a 16-in. motor pulley and 64-in. cast-iron lineshaft pulley mounted on 22-ft. centers. This lineshaft, which turns at about 225 r.p.m., is equipped with the Cleveland type collar-oiling bearings manufactured by the Hill Clutch Machine and Foundry Company, which are supported on hangers of the same make. We drain and refill the oil reservoirs once a month; beyond this they receive no attention.

* * * *

"ALL OF our drive equipment has been carefully installed and none of it is called upon to perform beyond its rating. That is one of the secrets of any power drive that gives satisfactory service." In the accompanying article the author explains the practical application of this secret in laying out and installing drives that are subjected to the heavy shock loads encountered in a drop forging plant.

THE MACHINES in the tool room are operated from a single lineshaft 80 ft. long, which is driven by a 50-hp. motor. As will be seen, the SKF ball-bearing hangers supporting the lineshaft are rigidly mounted on 5-in. channel irons placed back to back and bolted to the heavy I-beams that support the roof.

POWER is delivered to the plant at 220 volts and distributed from the board at the right to the various departments. The 150-hp. synchronous motor that drives the first section of lineshaft in the forge shop can be seen at the extreme left. The automatic control panel for this motor is at the left end of the switchboard. In the background is one of the motor-driven blowers for the heating furnaces.

* * * *

This section of the lineshaft drives twelve heavy hammers through 12-in. double belts. The hammer shaft pulleys over which the belts run range from 48 to 60 in. in diameter, whereas the lineshaft pulleys vary from 18 to 26 in. in diameter, depending upon the speed and make of the hammer. At the present time we are using Cleveland Oak belts here and find that they give good service on this kind of drive.

Part of the hammers are located on one side of the shaft and part on the other. Although this arrangement tends to equalize the pull on both sides of the lineshaft there is certain to be an unbalanced load most of the time. The hammers operate intermittently, of course, so that at a given moment almost any combination of hammers may be working. Thus, three or four hammers may be raised on one side of the shaft while only one or two are being lifted on the other side.

It is obvious, therefore, that the lineshaft had to be supported as rigidly and as strongly as possible. Furthermore, inasmuch as the drop hammers are from 15 to 18 ft. high provision had to be made for mounting the lineshaft a considerable distance from the floor.

These problems were solved by designing a very strong roof-supporting structure and mounting the lineshaft on the bottom side of the trusses. The hangers, which are spaced on approximately 10-ft. centers, are bolted to two double rows of 8-in. channel irons placed back to back and fastened on to the roof trusses. Pieces of 12-in. channel iron serve as footings for the hangers. The distance from the foot of the hangers to the floor is approximately 24 ft.

The second section of lineshaft in the forge shop is also 80 ft. long and $3\frac{1}{16}$ in. in diameter. It is supported by the same type of hangers and mounted in the same manner as the first section. A 75-hp. squirrel-cage motor is sufficient to drive this shaft inasmuch as only eight comparatively light hammers (minimum weight of falling parts, 1,200 lb.) are operated from it.

Conditions in the press department are much less severe than is the case in the forge shop, but they are by no means ideal. Here we operate eleven presses of various sizes and types for trimming the fins from forged parts, straightening them, and so on.

The eleven lighter presses in this department are operated from one $2\frac{15}{16}$-in. lineshaft that is 70 ft. long and is driven by a 40-hp., 1,200-r.p.m. squirrel-cage motor. This lineshaft is mounted in the same type and make of bearings and hangers that are used in the forge shop.

Conditions in our plant and particularly in the forge shop are hard on the drive equipment, but we have allowed what we consider to be ample safety factors to take care of heavy shock loads and other unfavorable operating features, and we do not anticipate having any unusual trouble with our power drives. All of our drive equipment has been carefully installed and none of it is called upon to perform beyond its rating. That is one of the secrets of any power drive that gives satisfactory service.

A LINESHAFT 70 ft. long drives the presses in the press shop. This lineshaft, as well as those in the forge shop, is mounted on Hill collar-oiling sleeve bearings and is driven by a 40-hp. motor at 230 r.p.m.

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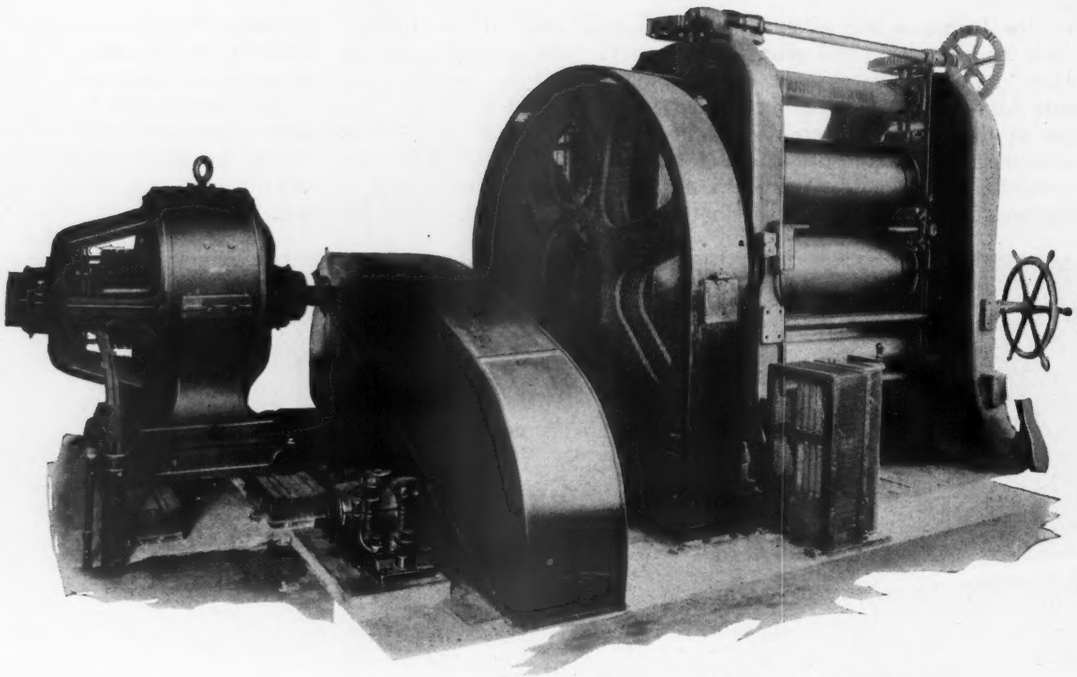


Shunt motor of 125-hp. rating driving a rubber calender. Field control gives a motor speed of 300 to 600 r.p.m., but operation on a three-wire, 125/250-volt circuit gives a 4:1 ratio, making the total speed range 150 to 600 r.p.m.

Fitting the MOTOR *to the Drive*

USE OF electric motors for driving the machinery in industrial plants has become so universal that it is utterly commonplace. However, the mere fact that motors are so widely used sometimes appears to lead to the erroneous belief that the selection of a motor for a specific application is more or less incidental and can be passed over lightly, or entrusted to someone of limited experience.

In the early days of the electric motor this viewpoint had at least the justification that production machines were much less complicated than they are today, motors were not available in the variety of operating characteristics that mark them now, and that less attention was paid to operating efficiency.

Now conditions are different. Many desirable characteristics that were unknown in the earlier designs have been incorporated in the present-day types. Great refinements have been made in the design of machines of all kinds, oftentimes resulting in complicated cycles of operation that make severe demands on the driving motor or motors. Finally, the efficiency of power utilization is an item that no plant can afford to overlook.

Together, all of these factors combine to make the proper selection and application of motors a matter that should receive skilled and careful attention.

The following discussion will serve to bring out the salient features of the different types of motors now available and the general classes of service for which they are best adapted.

C. W. DRAKE, *General Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.*—Motor application engineering may be defined as the choice of the proper motor for the particular work to be done. To do this properly requires, first, a good working knowledge of all commercial, industrial electric motors and, second, an intimate knowledge of the characteristics of the machinery to be driven.

Information of the first kind is probably the most readily obtainable, as it involves the fundamental characteristics of electric motors and these may be learned in various ways.

Information of the second type is much more difficult to obtain, as few books are written regarding the operating characteristics of the numerous machines used in the industries and those published are often partly obsolete shortly after, due to the continual changing of manufacturing conditions. The various trade or technical papers have many articles of this nature and probably constitute the best source of written information along these lines.

In considering the application of a motor to a certain machine the writer first tries to obtain a mental picture of the speed-torque characteristics of that machine and super-imposes that picture on the speed-torque curves of the various motors until one is found which most nearly gives the desired results. This is not nearly so difficult as it may seem, but it is necessary to determine at least the following details regarding the machine to be driven.

1. *Speed*—Does the machine operate only at one speed, or is a considerable speed range required? If so, how much?

2. *Torque*—If the speed is constant, is the torque or load constant or widely varying? If a wide speed range is required, is the torque constant over the entire range? If not, at what speed does the maximum torque occur? What is the ratio of the torque required to start the load compared with the normal running torque?

3. *Speed Regulation*—Is it essential that the speed be maintained approximately constant regardless of load changes, or is it satisfactory to let the speed increase considerably as the load is reduced? Is a flywheel installed on the machine? If so, what are its dimensions and its r.p.m.?

These three items are of primary importance in choosing the correct electrical characteristics of a motor, but there are many other items to consider, such as whether the load is continuous or intermittent, the mechanical connections between the motor and the machine, the mechanical modifications of the motor itself, such as horizontal, vertical, open, or enclosed type, and the type of control best suited to the application.

With this brief discussion of the mechanical side of the application problem we can now turn to the consideration of the electrical motors. These are broadly classified as alternating- and direct-current types.

Alternating-current motors may be classified as single phase and polyphase, although the manufacturing industries have comparatively little to do with single-phase motors. In general, the great majority of single-phase motors are of fractional horsepower and are used for domestic appliances, and for office and store devices, such as fans, and adding machines.

Single-phase motors of various types are built to meet a large number of special applications, such as portable tools, fans, etc., but the bulk of production in completely-assembled motors may be classified as split phase or repulsion-start induction motors, according to the type of winding or method of starting used.

Split-phase motors are essentially the same as two-phase, squirrel-cage induction motors with the addition of a centrifugal switch to open the starting winding as the motor approaches full speed. This simplicity of construction and consequent reliability and low cost are primarily responsible for the popularity of this type of motor in the domestic field. On the other hand, when starting it is a rather poor two-phase, squirrel-cage motor; so it is not surprising that it takes a rather high current from the line compared to the starting torque developed. This peak current on a lighting circuit causes a decided flicker in the lights, and the tendency of the power companies has been to reduce the size of motors of this type that may be used on the-lighting circuit.

Repulsion-start induction motors have a stator winding arranged for connection to the line and an armature or rotor winding connected to a commutator. The brushes on the commutator are short circuited which give the repulsion-starting characteristics and at a predetermined speed a centrifugal switch either short circuits the winding or changes the connections to give the equivalent of a squirrel-cage winding. The motor then operates at constant speed as a squirrel-cage motor.

Such motors have a high starting torque, generally three to four times full-load torque, and take only from two and a half to three times full-load current when started on full voltage. All of the present household refrigerating machines are using motors of this type and practically all the larger single-phase motors have similar characteristics, as they develop ample torque for all applications and start with a minimum of line disturbance.

Polyphase motors may first be classified as induction and synchronous. Induction motors are of two principal types, squirrel cage and wound rotor or slip ring, although there are numerous modifications of each type giving slightly different starting or running characteristics. An induction motor of either type is inherently a constant-speed machine and most applications of these motors come under this heading. Before discussing further the speed-torque characteristics of the various motors, it is well to obtain a clear understanding of the speed classifications as approved by the National Electrical Manufacturers Association. The definitions agreed upon in the 1928 Hand Book of Apparatus Standards are as follows:

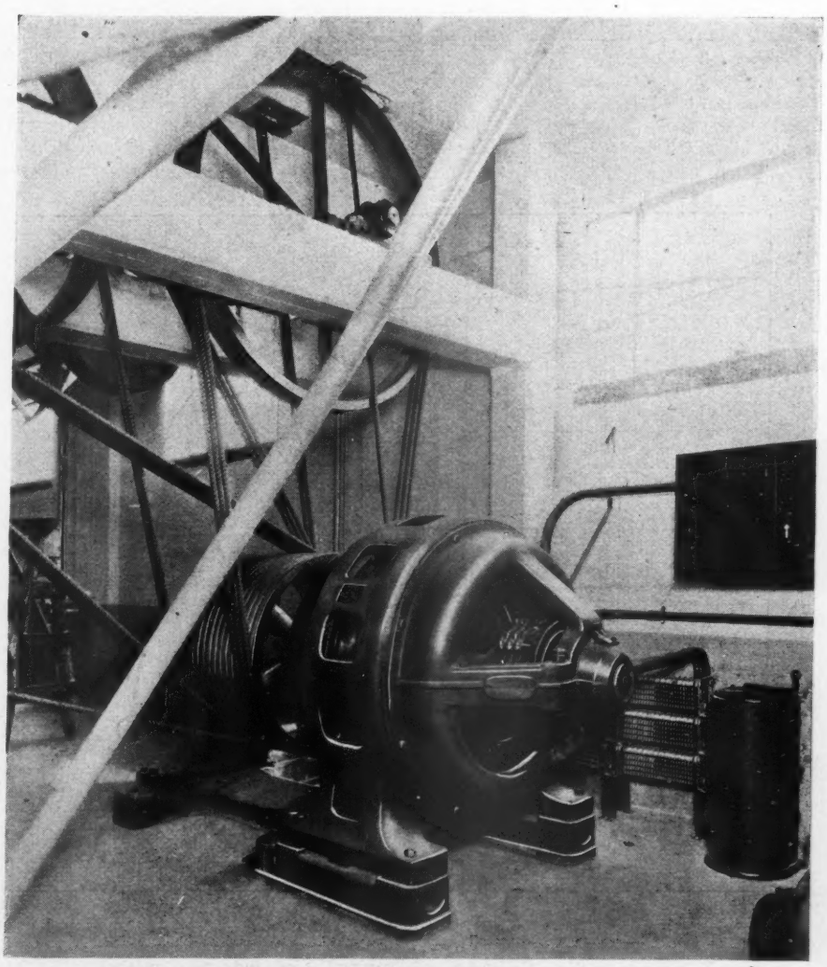
Constant Speed Motors—A constant-speed motor is a motor in which the speed is practically constant, as for instance an induction motor with small slip, an ordinary direct-current, shunt motor or a synchronous motor.

Varying Speed Motor—A varying-speed motor is a motor in which the speed varies with the load, ordinarily decreasing as the load increases, for example a series motor or a compound motor.

Adjustable-Speed Motor—An adjustable-speed motor is a motor in which the speed can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load; such as a shunt motor with field resistance control designed for a considerable range of speed adjustment.

Multi-Speed Motor—A multi-speed motor is a motor which can be operated at any one of several definite speeds each being practically independent of the load; for example a direct-current motor with two armature windings, or an induction motor with a primary winding capable of various pole groupings.

At the present time practically all makes of squirrel cage motors are so designed that they may be started on full voltage without exceeding the starting currents recommended by the National Electric Light Association in sizes up to 30 hp. Under this classifi-



HERE A 300-HP. wound-rotor induction motor is driving the line-shafts in a flour mill.

cation of line-start motors there are two distinct types, one generally known as the standard or low-starting torque and the other as the high-starting torque, double deck or similar designation.

The first class of motors meets the torque requirements agreed upon by the National Electrical Manufacturers Association, which, regardless of horsepower rating shall not be less than the following percentage of full-load torque with rated voltage applied.

Number of Poles	Starting Torque, Percent Full-Load Torque
2	150
4	150
6	135
8	125
10	120
12	115

Torques of these values are sufficient for the average requirements; consequently such motors are used for most applications. For more severe starting service, such as belt conveyors with high friction load, small refrigerating machines or plunger pumps starting against full pressure, motors with higher starting torque are desirable, and for these applications high-torque motors are available.

These motors develop a starting torque of two to two and one quarter times full-load torque with no greater starting current than the standard motors. Although they develop high starting torque, they are constant-speed, low-slip motors and should not be confused with the high-torque, high-slip motors obtained by the use of high resistance in the rotor circuit. On machines having large flywheels which are designed to help carry peak loads, as on shears, presses, etc., high-slip motors are desirable as a flywheel can give up energy only by dropping in speed. A constant-speed motor allows the flywheel to do very little work.

High-slip motors are also desirable for service requiring frequent starting, stopping and reversing, such as low-speed elevators, transfer rolls or live rolls, and conveyors in saw mills and similar industries. These motors give a high starting torque with a low starting current; when frequent starts and reversals are made the heating caused by the starting current is often much more important than the normal load current. Consequently, a motor that has a starting or locked current of about one-half the standard motor will give much better service under these conditions, and also may utilize a less expensive controller.

Typical speed-torque curves for varioue types of squirrel-cage motors are shown in one of the illustrations on this page.

It is possible to design multi-speed squirrel-cage motors with various relations between the torques obtained on the several polar combinations, but a common and quite normal design develops similar torques at both high and low speeds, although the torque at the reduced speed is generally somewhat less. Multi-speed motors are rated either on a constant-torque or on a constant-horsepower basis, the former being extensively used for driving the feeding mechanisms on woodworking and metalworking machines, and the latter for the cutting heads on similar machines. Constant-horsepower characteristics are required for most cutting heads, as the heavy cuts at low speeds take approximately the same power as lighter cuts at high speeds.

The usual characteristics associated with wound-rotor induction motors are really those obtained with the motor in connection with a controller and external resistance, as the motor itself with its rotor short-circuited has a performance similar to curve A in the illustration on this page, except the starting torque would be considerably lower. Due to the fact that the rotor winding is of phase-wound type with the leads brought out to collector rings, it is possible to connect in a controller and a ressistance which may be varied and cut out in steps as desired. By properly choosing the value of resistance, it is possible to obtain any desired value of starting torque up to approximately the maximum or pull-out torque.

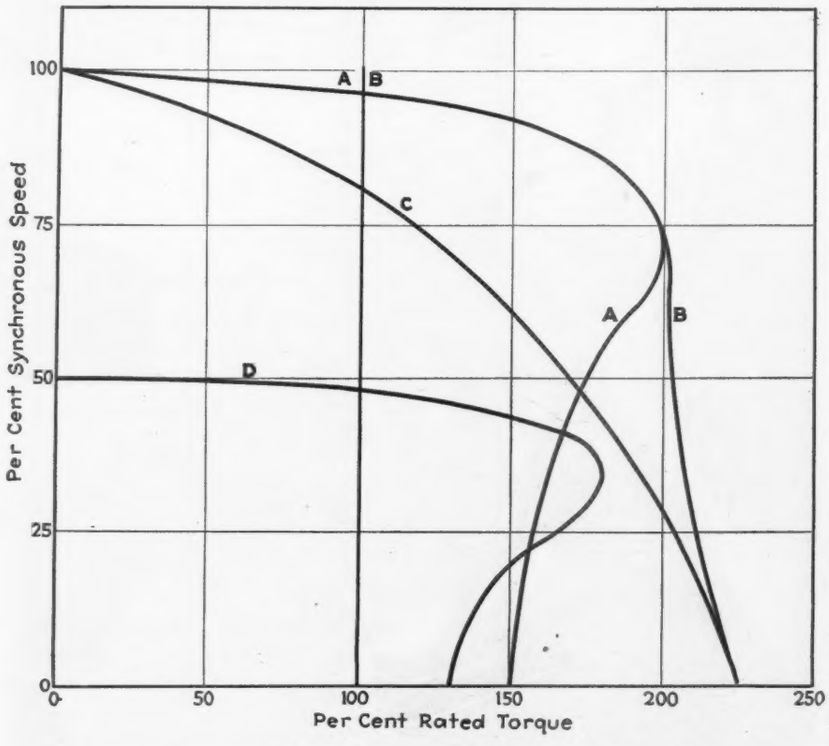
The current drawn from the line for a given torque is independent of the speed; so it is possible to start and accelerate a torque equal to the rated torque of the motor with only slightly more than the rated current if a suitable controller is provided. Wound-rotor motors are, consequently, well adapted for two constant-speed service, such as group drives in flour mills, paper mills, and so on, where there is a large friction load to overcome, and also for variable-speed service, which may again be divided into intermittent duty and continuous duty.

Under the first classification may be mentioned cranes, hoists, elevators, and the like, for which service a resistor designed for intermittent regulating duty is satisfactory. Under continuous duty are such applications as fans, pumps, dryers, and cement kilns, where continuous service at reduced speed down to approximately one-half speed is required. The resistors in these cases must be designed for continuous duty, and at one-half speed approximately one-half of the energy input to the motor is dissipated in the resistor.

As a wound-rotor with secondary resistance control gives varying-speed and not adjustable-speed characteristics, it is not satisfactory for loads having a widely varying torque, such as machine tools, since at no load the speed will be approximately synchronous speed, regardless of the controller setting or the speed at full load.

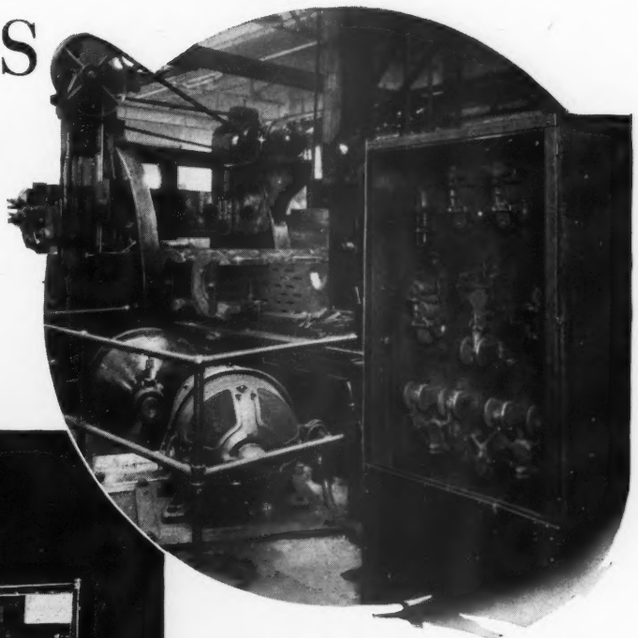
The rapidly increasing use of synchronous motors for general industrial applications is due primarily to an appreciation of the disadvantages of low power factor. As a synchronous motor performs two functions, that is, drives a mechanical load and produces leading reactive kilovolt-amperes, it is evident that the corrective kilovolt-amperes are obtained at a very low investment cost, generally considered as the increased cost of the synchronous equipment over that which would otherwise be required.

The field of application is, first of all, for constant-speed service, and as

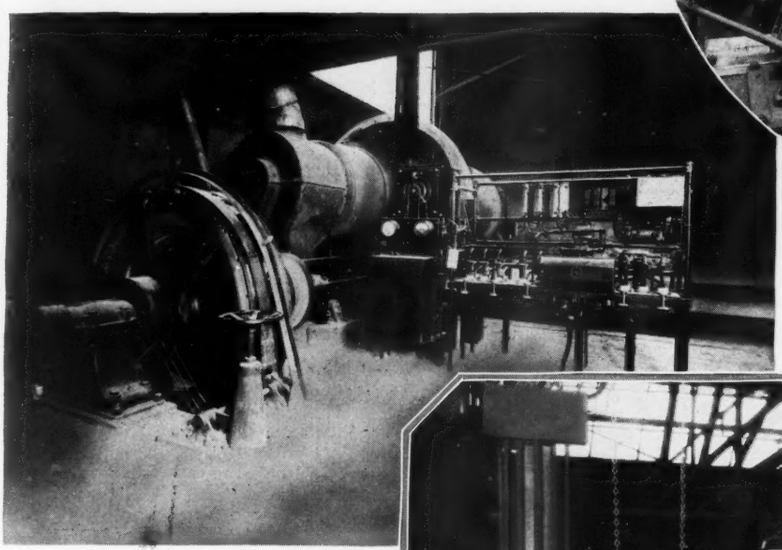


SPEED-TORQUE CURVES of squirrel-cage induction motors. Curve *A* represents a typical standard-torque motor; *B* is the curve of a high-torque motor; *C* is a high-torque, high-slip design. Curves *A* and *D* together represent a multi-speed, 2 to 1 ratio motor.

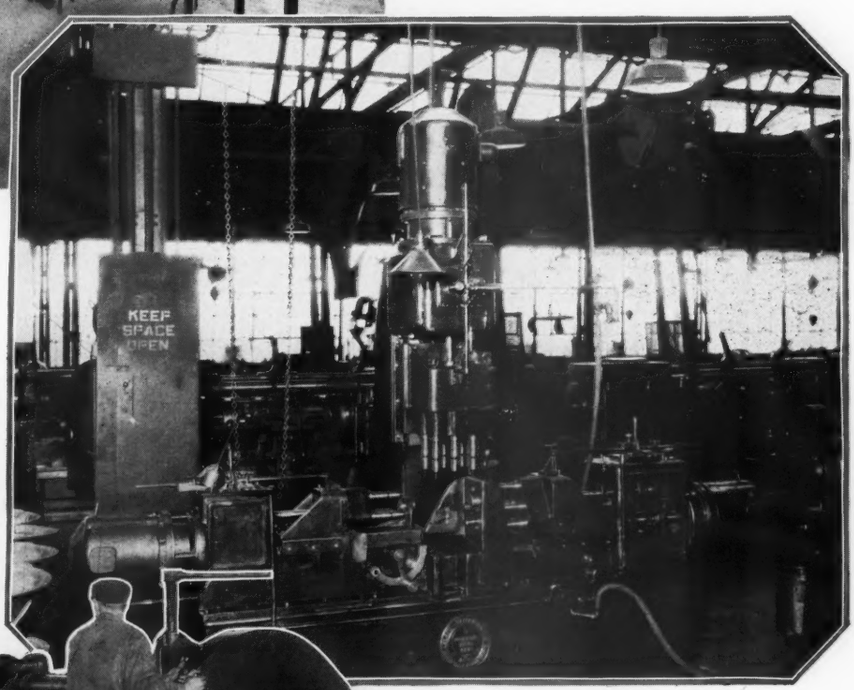
POWER DRIVES *and* CONTROLS *that Serve* INDUSTRY



HERE DYNAMIC braking is used to stop this d.c. motor quickly. When the main contactor is open a resistor is automatically connected across the armature of the motor.

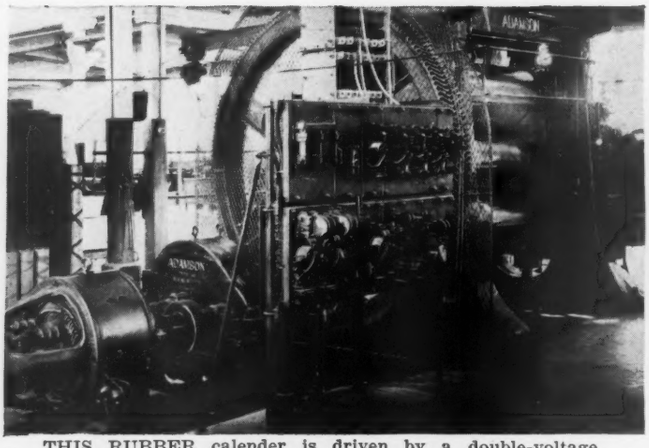


THIS 600-hp. 144-r.p.m. synchronous motor with automatic control drives a tube mill in a cement plant.

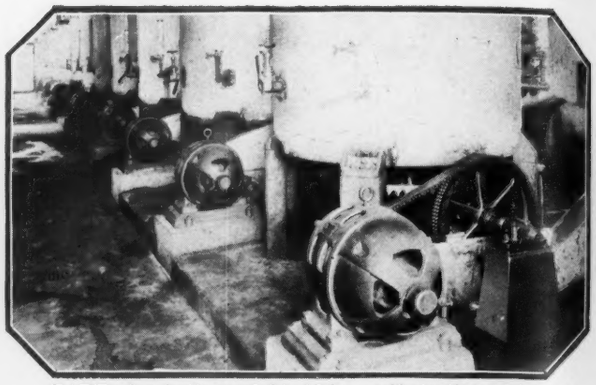


NOWADAYS many production tools employ built-in motors, as is the case of this three-way tapping machine, which is driven by a fully-inclosed, self-ventilated, squirrel-cage motor.

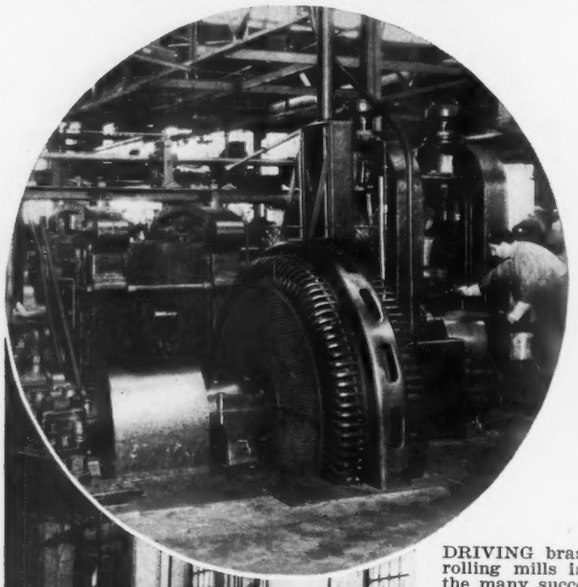
THE NECESSITY of operating this binding roll in either direction at several different speeds was met by using a compound-wound, d.c. motor, and reversing drum controller.

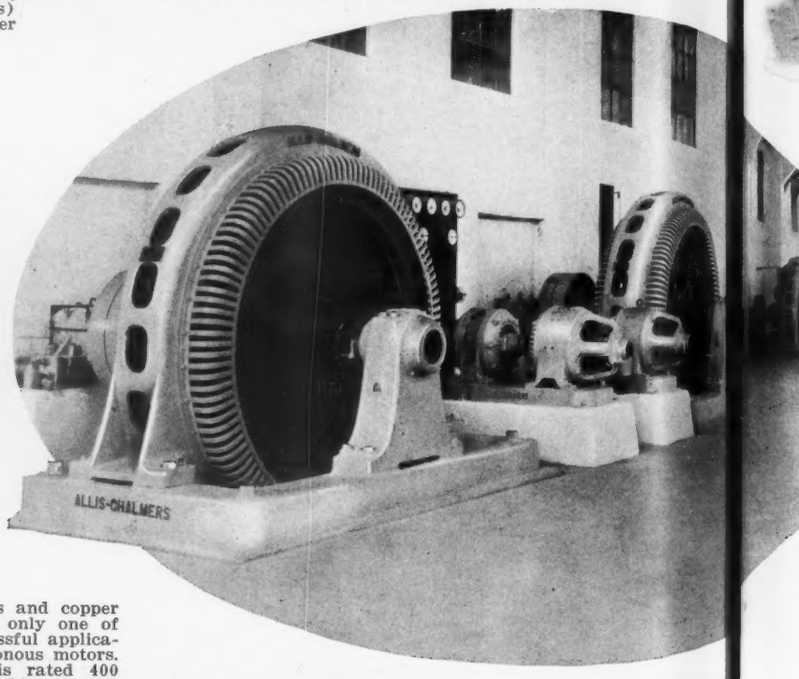


THIS RUBBER calender is driven by a double-voltage, adjustable-speed, d.c. motor. The lower voltage (115 volts) is used for operation at low to half speed, and the higher voltage (230 volts) for half to high speed.



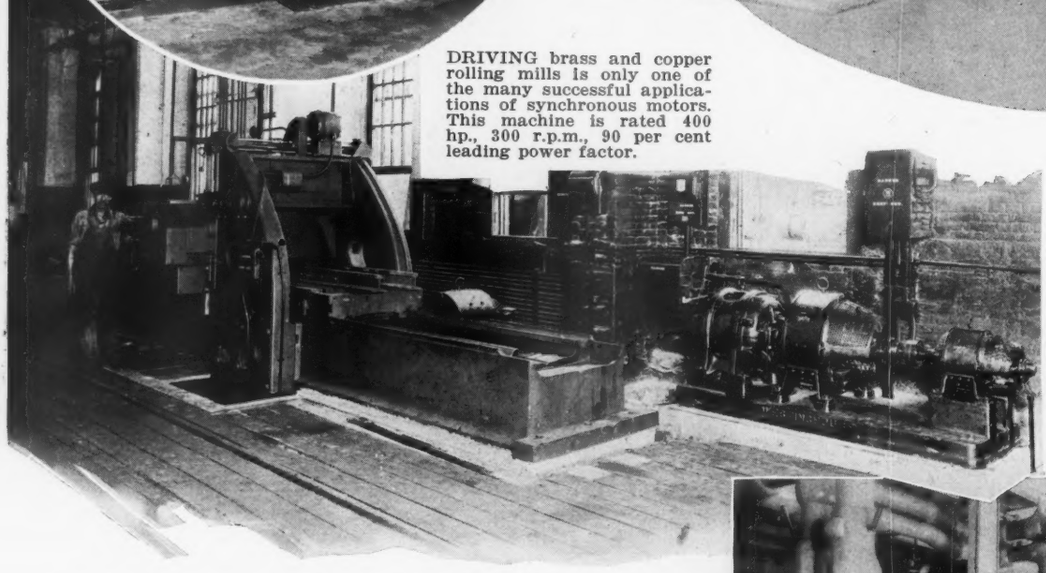
PART of a battery of 24, 15-hp., self-starting motors in a garbage reduction plant. The motors are connected to the load by silent chain drives, and controlled by push buttons operating across-the-line starters.



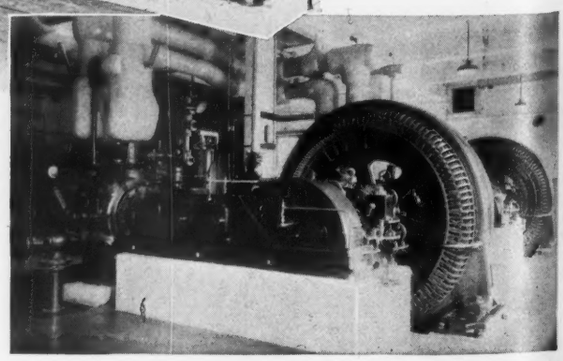


DRIVING brass and copper rolling mills is only one of the many successful applications of synchronous motors. This machine is rated 400 hp., 300 r.p.m., 90 per cent leading power factor.

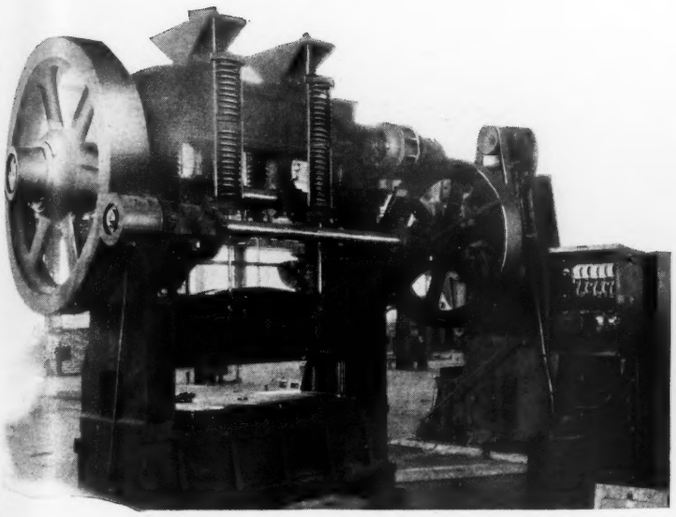
FOUR, high-torque synchronous motors rated at 800 hp., 2,200 volts, 180 r.p.m., 100 per cent power factor, drive the compeb mills in this cement plant.



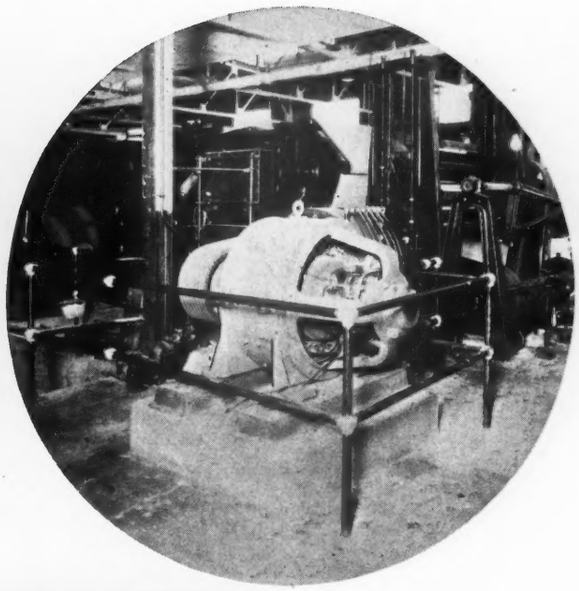
THE MOTOR driving this planer is controlled by the variable-voltage system. The motor-generator set with direct-connected exciter can be seen at the right.



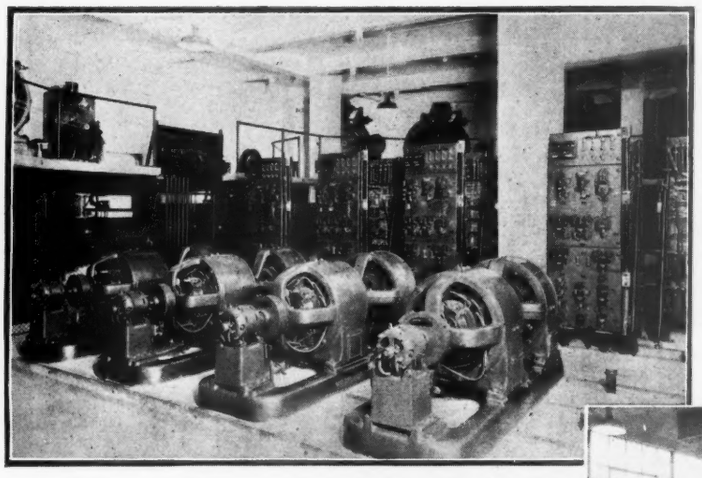
COMPRESSORS are an ideal application for synchronous motors. The two engine-type, 175-hp., 180-r.p.m., 100 per cent power factor motors shown here are driving two-stage ammonia compressors.



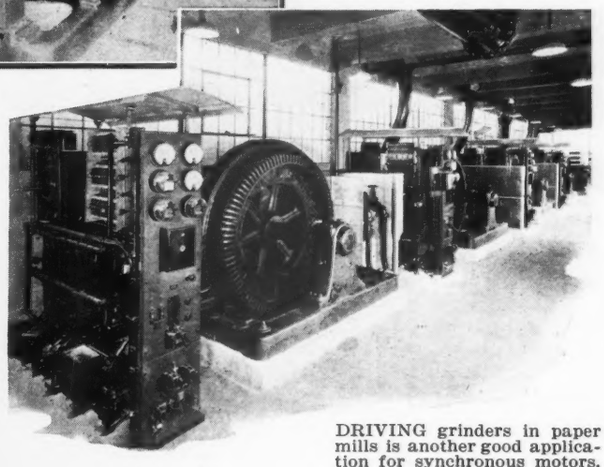
AN AUTOMATIC compensator controls this 15-hp. squirrel-cage motor which drives a shearing press.



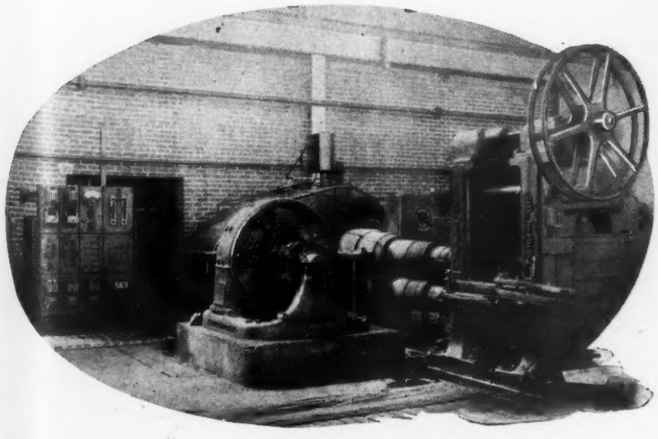
CONSTANT speed under changes in load must be maintained by the motors driving paper making machines. That condition was fulfilled here by using a 100-hp., 350/900-r.p.m., d.c. shunt-wound motor to drive this four-drinier-type machine, which is making 9-lb. tissue.



THESE motor-generator sets and control panels provide for the proper acceleration and braking of the motors that operate high-speed passenger elevators.

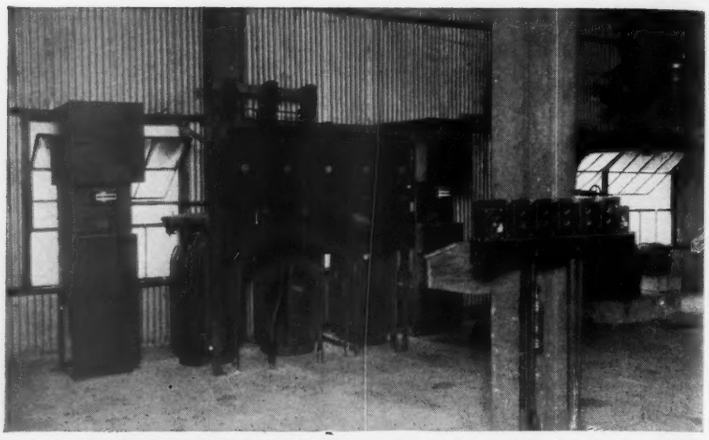


DRIVING grinders in paper mills is another good application for synchronous motors. In this mill five 1,000-hp., 2,300-volt, 240-r.p.m. motors are used in such service.

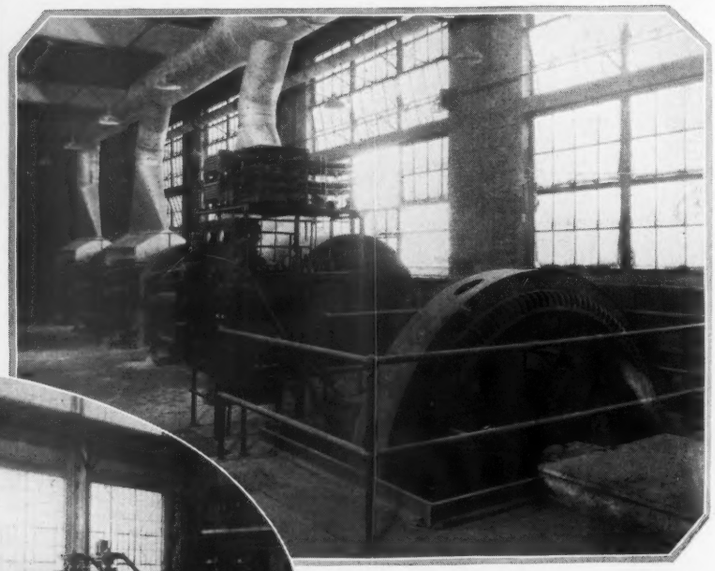


A PUSH-BUTTON station on the frame gives complete control of this 16-in. cold strip mill, which is driven by a 250-hp., d.c. shunt motor.

IN THIS PLANT a 250-hp., 100-r.p.m. synchronous motor is used to keep the power factor up, and is doing a good job of it.

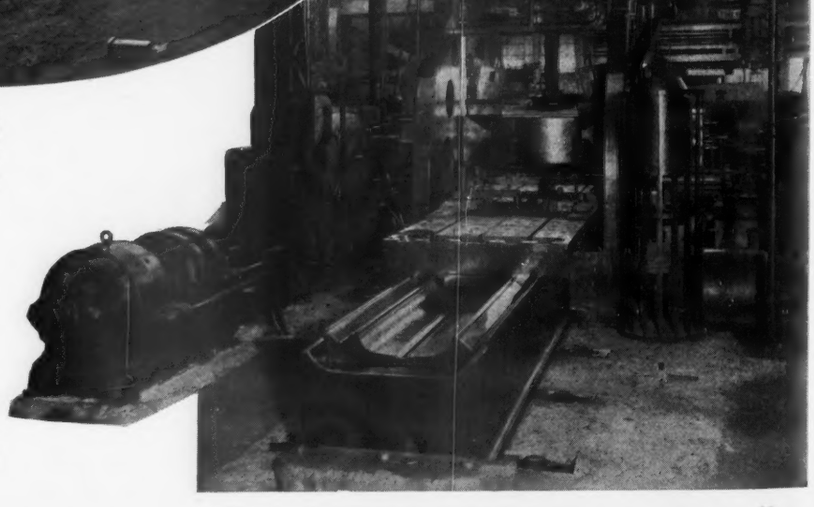


WITH PUSH-BUTTON CONTROL the control panels may be located in any convenient place away from dirt and dust or fumes. These are the panels for the kiln room motors in a cement plant.

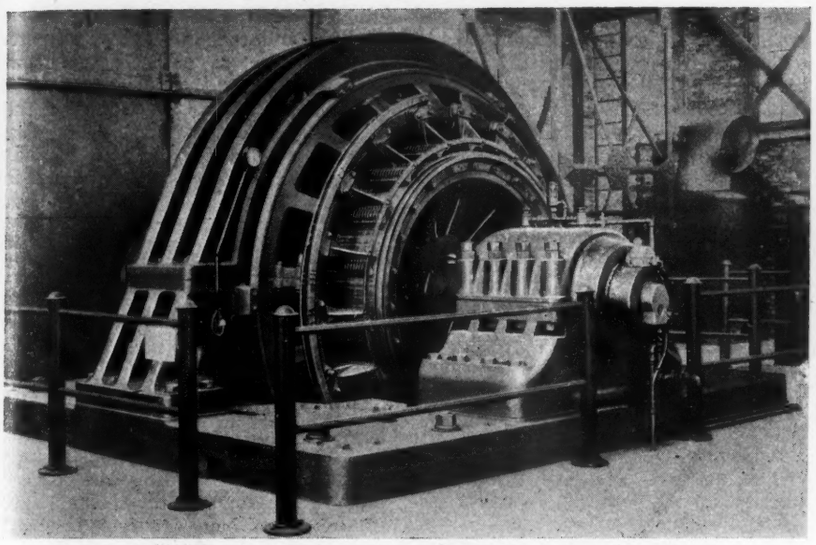


USE OF A synchronous motor makes it feasible to drive this rubber mill lineshaft at the desired speed, 120 r.p.m., without resorting to a speed-reducing device. The motor is rated at 600 hp., 2,200 volts.

A SPECIAL compound winding is used in these 150-hp., d.c. motors to give the speed-load characteristics required for driving the 12-in. cold strip mills shown here. These mills operate in tandem, rolling the steel under tension as a continuous process.



IN THIS high-speed planer drive, current for the driving motor is supplied by a motor-generator set. The speed and direction of rotation of the planer motor are controlled by varying the strength and polarity of the generator field.



DIRECT-CURRENT MOTORS are widely used in large sizes in steel mill service where reversing is necessary. This is a 4,500-hp., 750-volt, 120/255-r.p.m. motor driving a large skelp mill.

* * *

a rule for drives requiring about 50 hp. or over. The size is only an economic factor, since synchronous motors down to 5 hp. rating have been built, but for moderate power requirements it is usually more economical to use simple squirrel-cage motors and correct the power factor in large units, or by other means. Up to a few years ago synchronous motors were considered only for compressors, fans, pumps and similar applications which had a definite and rather light starting duty. Now with the improved design of motors available it is difficult to state where the line is between the field of the induction and the synchronous motor.

Practically any constant-speed load that can be driven by a squirrel-cage motor can be driven equally well by a synchronous motor and many cases have lately appeared where synchronous motors are being used in place of wound-rotor motors. In the latter case there is no question about the synchronous motor taking more current than the wound-rotor motor at starting, but if this is not objectionable nearly any desired starting or pull-in torque can be obtained.

In considering the application of a synchronous motor to any machine, consideration should first be given to the values of torque required at starting, when pulling into synchronism, and the maximum running or pull-out torque. A centrifugal pump or fan requires very little starting torque, but this increases rapidly with the speed and with discharge open will require full-load torque when pulling into synchronism. There will be practically no overload under normal conditions.

A lineshaft group drive might have high static friction to overcome at starting, but with the machines empty or idle might take little power to accelerate or pull in. The running load, however, like that of a rubber mill may vary rapidly from nearly zero to 100 per cent or more overload. Motors can be obtained with a wide range of torques varying from the compressor motors with about 50 per cent starting and 40 per cent pull-in to motors having 225 per cent starting and 125 per cent pull-in. In connection with loads having flywheels it should be remembered that if these have been used to reduce peaks by dropping in speed, the synchronous motor will have to carry all the peaks actually caused by the machine operation.

Synchronous motors are rated both on a 100 per cent power factor and on an 80 per cent power factor basis. The former, or unity power factor motor, gives no reactive kva. at full load and very little at lighter loads. Being cheaper than the 80 per cent power factor motor it is used either where low cost is important or where no extra power factor correction is required. An 80 per cent power factor motor at full load gives a corrective kva. of 60 per cent of its rated input kva. For instance, a 200-hp., 80 per cent factor motor would take approximately 200 kva. input and would have a corrective effect of 120 kva. that is equivalent to the addition of that amount of capacitors in the circuit.

An error sometimes made in choosing a synchronous motor is to select an oversize, 100 per cent factor motor, with the idea that the extra capacity will be available for power factor correction. If the load is 200 hp. or below and power factor correction is desired, it does little good to specify a 250-hp., 100 per cent power factor motor; what is needed is a 200-hp., 80 per cent power factor motor. In other words, consider the two functions separately and determine how much load there will be and how much corrective effect is desired.

G. E. REIFF, *Electrical Engineer, Allis-Chambers Manufacturing Company, Milwaukee, Wis.*—Using the type of winding as a basis, d. c. motors may be divided into three classes: shunt, series, and compound. Each of these classes has distinctive performance characteristics and, broadly speaking, certain fields of application to which it is particularly well suited. These characteristics and fields of application may briefly be described as follows:

The shunt motor consists of an armature winding, an interpole winding, in series with the armature, and a field winding called the shunt winding because it is shunted across the two main line terminals and has full line voltage impressed on it.

The chief characteristics of this type of motor are constant field strength and practically constant speed from no load to full load. (Shunt motors have a slightly drooping speed characteristic due to the IR drop in the armature.) The torque curve is proportional to the armature current.

Applications are principally where constant speed is required and starting and stopping are not frequent, such as driving lineshafts, for individual drive of machine tools, and driving ventilating fans. In general, shunt motors find use in all applications where the load and speed are practically constant and the starting torque is not heavy, the load being applied after the motor attains full speed.

Shunt motors are also well adapted to adjustable-speed requirements, as the speed can readily be varied by inserting a certain amount of resistance in the shunt field circuit. Therefore, they find a wide field of application in the individual drive of a large variety of tools, such as lathes, drill presses, milling machines and grinders.

Series motors are distinguished by an armature winding, an interpole winding, and a field winding that is connected in series with the armature and interpole windings and always carries the full-load armature current. The series field consists of a small number of turns of large-sized wire, as compared with the field winding of a shunt motor, which consists of a large number of turns of small-sized wire. The shunt field has full line voltage on it, whereas the series field has a small fraction of the line voltage across it.

One of the characteristics of series motors is that the field strength varies—depending upon the load. Light loads give a weak field and high speed, whereas heavy loads give strong fields and low speed. For this reason the speed characteristic is decidedly drooping. Series motors develop a high torque, which increases in greater proportion than the load.

In general, series motors are used where the load is direct connected and heavy starting torque is required. A series motor should never be belted to its load, for if the belt should come off the motor would run away, as it would have practically zero field strength. Their widest use is on cranes and hoists, and in traction work. There are also many special applications, such as tilting motors for electric furnaces, for adjusting the carbon electrodes in such furnaces, and for operating large hydraulic gate and butterfly valves.

Compound motors have an armature winding, an interpole winding in series with the armature, a shunt field winding, and a series winding in series with the armature. They are thus a combination of shunt and series motor. The series winding is usually about 20 or 25 per cent of the total field, based on field strength. There are some special cases where the series field may be 40 or 50 per cent of the total, as in the case of self-starting motors.

Obviously, the characteristics of a compound motor are between those of the shunt and the series motors. It has more of a drooping speed characteristic than the shunt motor, but not so much as a series motor. It will develop more torque, drawing the same current from the line, than the shunt motor, but at a greater drop in speed. It has the advantage over the shunt machine in torque characteristics, and particularly for starting under load.

The compound motor is particularly applicable to drives having a large number of moving parts that must be put in motion when starting. Also, in the case of centrifugal pumps or blowers where the load increases as the cube of the speed, the compound winding tends to hold the speed at normal value and thus keep the motor from being overloaded.

S. P. BORDEAU, *Electric Machinery Mfg. Company, Minneapolis, Minn.*— Of the different types of a.c. motors available, the synchronous motor possesses a number of desirable characteristics that have resulted in a rapidly winding field of application on industrial, constant-speed drives that require a motor of 25-hp. rating or larger.

The outstanding features of the synchronous motor are these: (1) Constant speed, regardless of variation in load or variation in voltage. (2) It can be directly coupled to the load at any speed down to the very lowest. (3) It operates at a high power factor. (4) It operates at a high power conversion efficiency. (5) It is of simple, rugged construction. (6) It is competitive in first cost, especially in the lower speeds, with the induction motor.

The value of some of these characteristics becomes apparent when it is realized that absolutely constant speed, for example, insures maximum production and uniformity of product from the driven machine, a factor of obvious importance in such operations as grinding and crushing. Direct coupling to the load is of great advantage in saving of floor space and in the elimination of mechanical speed reducers, making possible savings of power in conversion and assuring freedom from loss in production due to break-down in speed reducing devices.

The electrical conversion efficiency of the synchronous motor is high at all speeds. At low speeds the efficiency is much higher than that of induction motors of equal rating. This advantage of the synchronous motor makes possible considerable savings in power cost, a factor of considerable importance in industries using large amounts of power, such as the refrigeration, pulp and paper, cement and rubber industries.

The inherent characteristics of the armature and the rotor of the synchronous motor permit a rugged mechanical construction that insures minimum maintenance expense. The large air gap minimizes attention and maintenance to bearings. In first cost, especially in slow speeds, the synchronous motor is competitive with other forms of drive. Also, at slow speed, full-voltage starting can often be used, giving greater simplicity than reduced-voltage starting, which is necessary with high-speed motors. In many instances the slow-speed synchronous motor directly connected to its load is less in first cost than high-speed induction motors with speed-reducing devices.

The unusual performance now obtained with the synchronous motor has, to no little degree, been furthered by modern control equipment now obtainable. Starting of a synchronous motor by the frequency relay system insures changeover from reduced voltage, where the motor is started on reduced voltage, at a definite motor speed. It also insures application of direct current excitation to the field of the motor, both in reduced-voltage and full-voltage starting, at a definite, correct motor speed, regardless of the load on the motor, or the time required in getting up to synchronous speed. It also permits resynchronization of the motor after a momentary power interruption where the motor has sufficient torque to pull the load into step or where means are provided, to unload the driven machine. The frequency relay system of control allows resynchronization after the motor has been pulled out of step by momentary overload, minimizing interference to production. Full protection is afforded the motor, making its operation as fool-proof and simple as that of the squirrel-cage motor.

Drives to which the synchronous motor is not applicable are those that require variable speed or that need a slip in speed to take advantage of flywheel effect. In some instances extremely high starting torque and pull-in torque requirements limit its use. Former limitations of the synchronous motor as regards first cost in the small sizes at high speeds, due to the high cost of automatic control, have largely been removed with simple forms of semi-automatic starters, using automatic field application.

Considering some of the industrial applications, synchronous motors are now widely used for air and gas compressors in every type of industrial plant, and for ammonia and carbon dioxide compressors in the refrigeration industries. The advantages of direct connection to the compressor at medium and low speeds, of high power factor, high efficiency and minimum floor space requirement have made its use for these applications almost universal. In industries such as the refrigeration industry, where the cost of power is a considerable item high efficiency is of outstanding importance. Synchronous motors are also widely applied to fans and blowers because of the advantages mentioned.

Every type of pump in industrial service is being driven successfully with synchronous motors, including centrifugal pumps for municipal and industrial water supply service, sewage handling and irrigation; screw pumps for low-lift sewage storm water service and irrigation; reciprocating or plunger pumps for hydraulic pressure work, pumping oil; and rotary pumps for handling heavier viscous liquids.

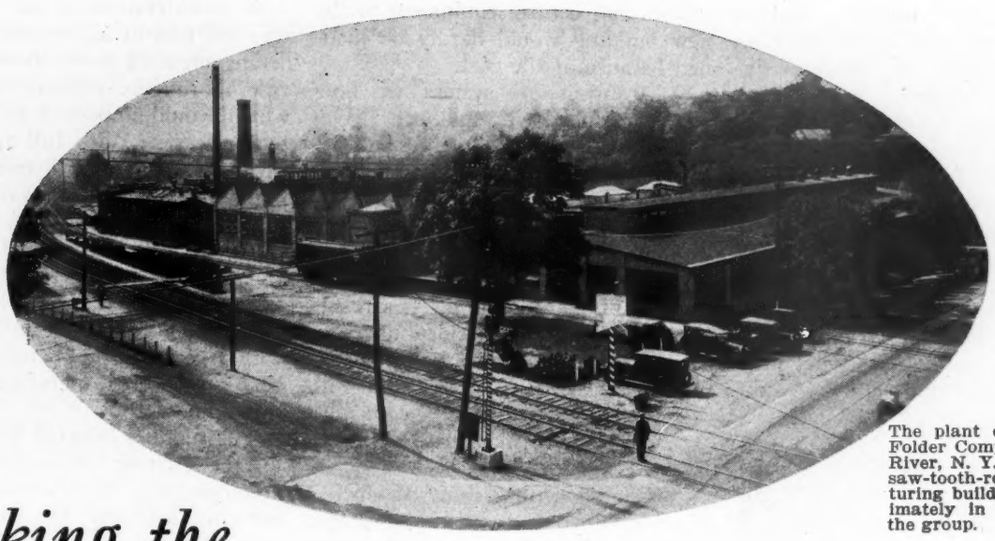
Special designs, incorporating high starting, pull-in and pull-out torques, have made possible application to such severe drives as the hammermill crusher and hogs—drives which in many cases have heretofore been considered unsuitable for the use of synchronous motors.

These motors are also widely used on motor-generator sets, the constant speed of the motor being reflected in better regulation of the generator voltage.

In the same way, synchronous motors find wide application in the pulp and paper industry. For grinders, the efficiency of the synchronous motor and its inherent adaptability to the grinding load leave no reason for the consideration of any other type of motor. Beaters were long considered to present too difficult a starting load for synchronous motors. They are difficult to start, but are now being successfully driven by these motors. Jordans are practically always driven with synchronous motors. The low operating speed of around 400 r.p.m. generally places this application in a class where synchronous motors are much to be preferred over induction motors. On pulp screens, economy of space, lower maintenance and higher efficiency make the use of these motors desirable.

In the rubber industry high-torque, low-speed, coupled-type synchronous motors are extensively used, direct connected to mill lineshafts. Quick stopping to meet safety requirements is obtained by means of plugging or dynamic breaking control. On Banbury mixers synchronous motors are successfully applied by special designs incorporating high-starting and pull-out torques. The rubber industry also uses synchronous motors on many of the applications previously mentioned, such as hogs, centrifugal pumps, reciprocating pumps, air compressors, ammonia compressors and d.c. generators.

In cement mills the synchronous motor finds application on compartment ball mills, crushers, and for other miscellaneous equipment. Other important applications made possible by modern, high-torque designs are rolling mill drives in brass, copper and steel mills. Simplicity of control together with constant speed and rugged construction makes the use of the synchronous motor very desirable for this type of drive. For use in steel mills, synchronous motors are available with the proper characteristics for piercing mills, tube rolling mills, reelers, merchant mills, rod mills and in fact practically every type of hot metal mill that operates at constant speed.



The plant of the Dexter Folder Company, at Pearl River, N. Y. The modern saw-tooth-roof manufacturing building is approximately in the center of the group.

Making the POWER TRANSMISSION SYSTEM *keep pace with Intensified Production Demands*

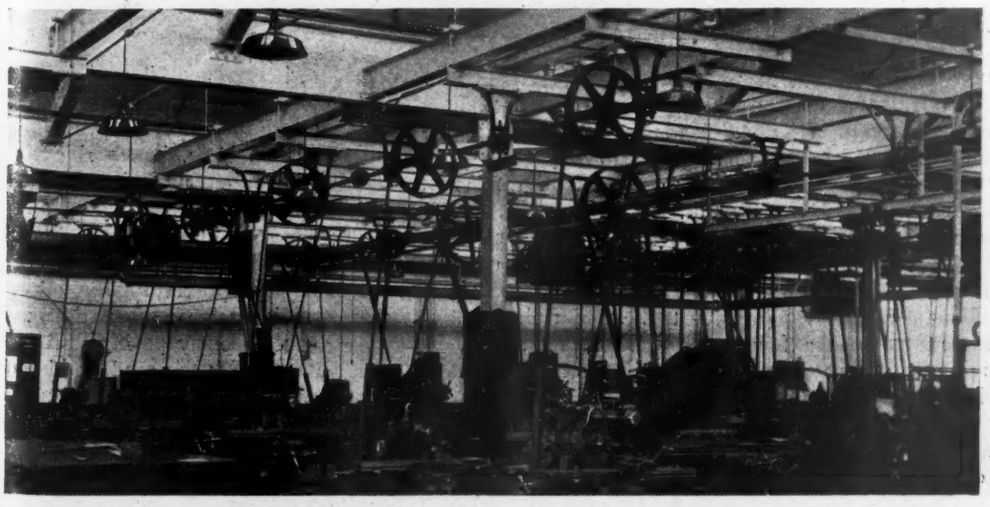
as told to W. THOMSON LEES

BY O. D. REICH

Works Manager,
Dexter Folder Company,
Pearl River, N. Y.

THE DEXTER Folder Company, manufacturers of folding machines used in the printing industry, located their plant some 34 years ago in Pearl River, N. Y. Thirty-four years is a comparatively short time, perhaps; but when measured in the light of industrial progress, accepted practice today and accepted practice 34 years ago seem centuries apart. Particularly is this true in the case of mechanical power transmission, in which common practice of even ten years ago has today become obsolete.

At Pearl River, for example, the buildings originally occupied were of brick, with joist type floors and roof. The power plant supplied 110 v. direct current, generated by several small units. Machinery was driven through line shafting and jack



NOTE the method of suspension of shaft hangers, permitting rearrangement with a minimum of labor. This view shows a part of the gear cutting and finishing departments.

shafts, on babbitt bearings, and in many cases the belt drives were on too-short centers. As business expanded, new buildings were added, and the power transmission layout expanded in somewhat of a hit-or-miss fashion. In other words, conditions were typical of the average growing plant of the period.

By 1920, expansion of business reached a point where greater plant capacity was required, and at the same time it was realized that to keep in step with general industrial progress, lower manufacturing costs would be imperative. Machine tools

WHEN this Fellowes gear shaper was put on its mettle for intensive production, the belt drive developed a dangerous whip. A heavier belt, better suited to the drive, remedied the trouble to a large extent.

ON THIS Cincinnati grinder, it was not a question of substituting heavier belts, but of meeting both moisture conditions and the side-slip requirements of the carriage drive.

* * * *

were crowded and badly arranged for routing material through processes; buildings were old, and not substantial enough to stand the weight and vibration of modern heavy fast-running equipment.

It was decided to tear out substantial portions of the old plant and erect a modern reinforced concrete structure of one story and basement, with saw-tooth roof, to house the main manufacturing departments.

At this time, machine tools in the erecting department had already been provided with individual drives and automatic controllers, which gave thoroughly satisfactory operation. In planning improvements for the new manufacturing building, this point was given consideration. Estimates showed, however, that complete equipment of individual motors and control equipment in the new building would hardly be justified because of the cost.

A transmission system of line-shaft, countershafts, and belt drives would be least expensive, but involved certain drawbacks. Nevertheless, as the greater part of the necessary motors, shafting, hangars and belting was already available, it was economically sound to take that factor into consideration. As a result, a combination was decided upon, of the two types of transmission; group drives for certain machines, and individual, automatically controlled drives on those machines which required them.

Beginning with a study of efficient machine layout, based upon proper routing of work and at the same time making provision for future expansion, the transmission system had to be planned with three other factors in mind. Since these are common to many plants which contemplate modernizing their power transmisison, it may be worth while to enumerate them:

(1) The economic advisability of utilizing as much as possible of the existing transmission equipment.

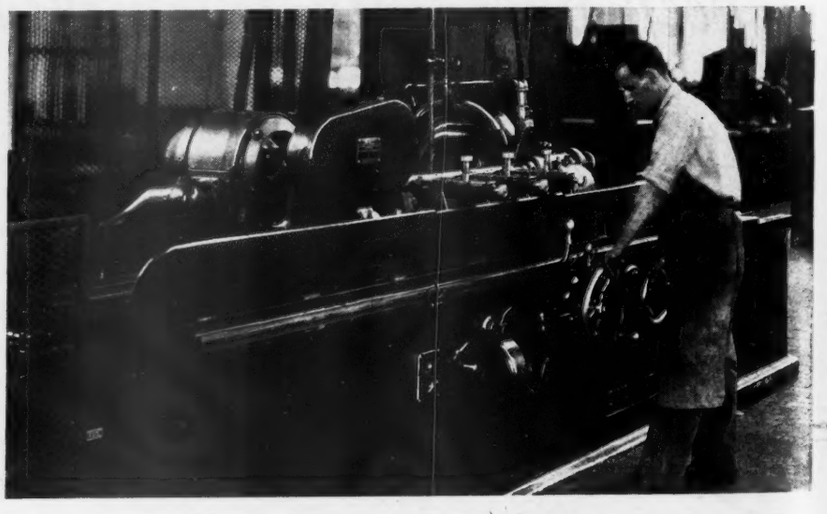
(2) The necessity for keeping frictional loads to an absolute minimum, because load demands were close to the maximum output of the power plant.

(3) The necessity of providing for later modernization of the power plant itself—a step which would have to be undertaken within a few years. This meant a probable change from 110 volt to 220 volt current, and involved providing for balanced loads, later on, of the 110 volt motors which would still be good enough to keep in service.

A consideration of all these factors led, first of all, to a very careful arrangement of group drives, to provide thoroughly efficient belt drives which would impose a minimum of power losses. With full appreciation of the merits of anti-friction bearings, the types then available were investigated. It was found that the Chapman ball bearing not only provided a long support for the shaft—an advantage, with heavy belt pulls—but it could be used in connection with the existing hangers. These bearings were therefore adopted throughout.

The method adopted for suspending the shafting (shown in one of the accompanying illustrations) provides extreme flexibility, since the hangers may be moved along the channel beams, and the latter may be moved along the I-beams, in each case simply by loosening the bolts. If desirable, the supporting I-beams can also be shifted with respect to the girders to which they are bolted.

Six years' operation with the modernized transmission installation has borne out the wisdom of the step. While power transmission is only one item, it is a large item, in manufacturing costs—not only directly, in the cost of power per production unit, but indirectly, in its ability to help or to hamper in getting full productive capacity from every machine.



The latter point was brought out rather forcibly, during the past year. We had been proceeding on a program of intensive cost-cutting and were simultaneously pushing production, in step with the modern idea of enlightened management; resulting in lower manufacturing costs, higher wages, and a more punishing pace for the mechanical equipment.

Time studies showed that there was a considerable gap between the actual production, on certain machines, and the estimated production capacity.

In a number of cases it was found that a disproportionate amount of productive time was being lost through necessary belt repairs. In many cases, belt slippage was responsible for holding down the production capacity of the machine tools.

In such a situation, with the men all on a premium wage-payment plan, the direct power loss was a minor item in comparison to the indirect losses which affected (1) production; (2) maintenance costs; (3) morale, because it affected the men's ability to earn more money.

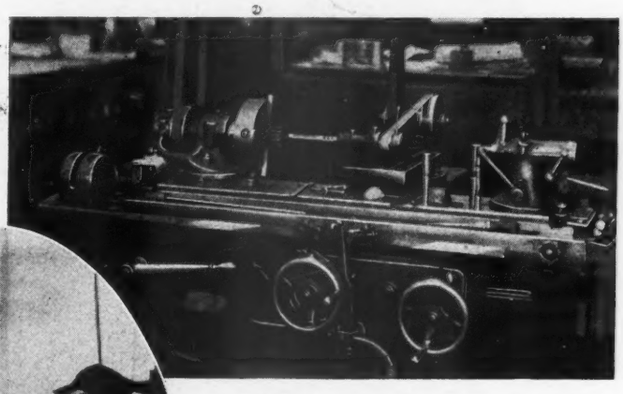
We put the problem up to the man who sold us our belting. He, in turn, called in his company's sales manager, Roy C. Moore, of the Chas. A. Schieren Company, who suggested that his engineers make a survey of our entire plant and then prepare recommendations to cover our belting requirements.

Just as in the case of the transmission layout of seven years ago, it was the practical considerations, rather than the theoretical, which had to govern these belting recommendations. If, in 1921, we had been unhampered by the economic requirements of utilizing equipment on hand, probably the resulting power transmission system could have been made even more efficient. Similarly, if it were not necessary, for economic reasons to keep the number of different kinds and sizes of belting as low as possible, probably some of our drives might be made more efficient by the use of a special belt. Also, if it were possible to put wider pulleys on some of our machines (which it is not) there are cases where the drives could be better taken care of. These, however, are purely theoretical considerations, and it is the practical conditions that have to be met, in our plant as in every other.

As a result of the survey, recommendations were made, covering each individual drive in the plant. In some cases, special belting was specified, but in the main the recommendations were for light double or regular double in place of single ply, to take care of the increased loads. In several instances, this would permit the use of a narrower belt, an advantage where either stepped cone or flanged pulleys were concerned for these types of pulleys had been source of trouble to us in the past.

These recommendations were not intended to be put into effect at one fell swoop, but to be followed out gradually, as belt replacements became necessary. Where they have been effected, improvements in some cases are notable, in other cases it will take time to prove results. Flagrant cases of slippage have been overcome; one instance where a belt used to whip dangerously under load, has been cured; the amount of time out for belt failures and repairs has been materially cut down.

Summing it all up, we are well pleased with the results obtained by the steps so far taken toward modernizing our power transmission. That does not mean that we are satisfied, however, because we are well aware that what is the best possible, today, is quite likely to be obsolete tomorrow. Even now, we are looking toward a new power plant; and this will bring, in its turn, more improvements in an already fairly efficient and modern power transmission system.



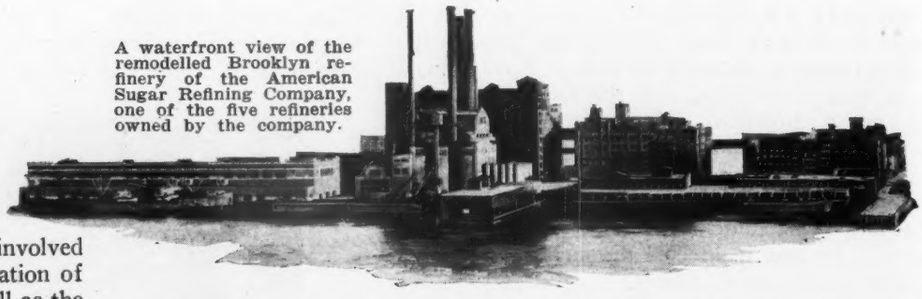
THE ADOPTION of a better grade belt permitted using slightly narrower belting on the flanged pulleys of this Brown & Sharpe grinder, as well as improving the general service efficiency of the drives.

THE DRIVE on this Gleason gear cutter is another instance where a double instead of a single ply belt not only gives longer life, but permits the use of a narrower belt; with consequent economy and reduction of side wear.

* * * *

BELT DRIVES on flanged spindle pulleys have always been a source of trouble, everywhere. A special spindle belt has helped, here, while a special double-ply on the main drive reduces lost time considerably.

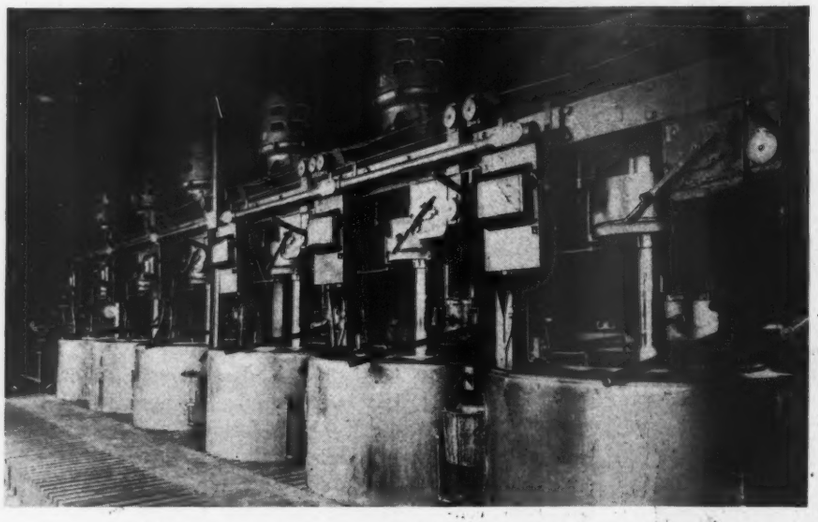
We SAVED *both* SPACE *by* REVISING *our*



A waterfront view of the remodelled Brooklyn refinery of the American Sugar Refining Company, one of the five refineries owned by the company.

THE REMODELING of the Brooklyn refinery of the American Sugar Refining Company, completed last year, involved among other things the relocation of much of the machinery as well as the purchase of new. Power drives were required in the new locations and the time was most favorable for replacing the old drives with modern ones.

As in most of the older plants the machines, in general, were arranged for group drives, the power was transmitted from the engines or motors through belts to line shafts and the individual machines controlled through the medium of friction clutch pulleys and more belts. Where considerable change in speed was required, an extra countershaft was necessary, with additional pulleys and belts.



A BATTERY of raw sugar centrifugal machines, showing the application of direct motor drive on high speed vertical spindles.

* * *

While this type of drive, in use for so many years, did transmit the power with fair efficiency, objections to it are numerous and obvious. The floor space required for the long belts is valuable and in some cases absolutely necessary for other purposes. The bearings requiring lubrication in a large plant are legion. The belt guards necessary for the protection of employees are expensive, hard to keep clean and are decided obstructions to proper illumination and ventilation. The stretch in the belts, particularly new ones, is objectionable, and in plants running twenty-four hours a day, the time lost in shortening the belts reduces the output of the machines involved.

Atmospheric conditions in many plants adversely affect belt drives; in moist places the pulley adhesion is bad, and in dry, dusty places the static electricity developed is often very objectionable, necessitating the use of "combs" and carefully grounded shafting and machinery. The modern drives installed overcame these objections almost entirely.

* * *

All of the water and most of the sugar solutions in the refinery are handled by centrifugal pumps and here, where the speed is high, the motors are attached directly to the shaft of the pump by a flexible coupling and both motor and pump are mounted on the same baseplate. The power transmitted to the shaft is entirely torsion and overcomes the objectionable side pull developed in the belt driven pumps.

The heavy syrups that are too viscous to be handled by centrifugal pumps are pumped by horizontal duplex reciprocating pumps. The motor is mounted on a base cast on the pump frame, directly above the pump, and delivers its power to the pump through a single pair of gears which are protected by a solid metal guard. The pump frame is of heavy construction to prevent distortion due to the motor load. This is a compact unit occupying the same floor space as the pump alone.

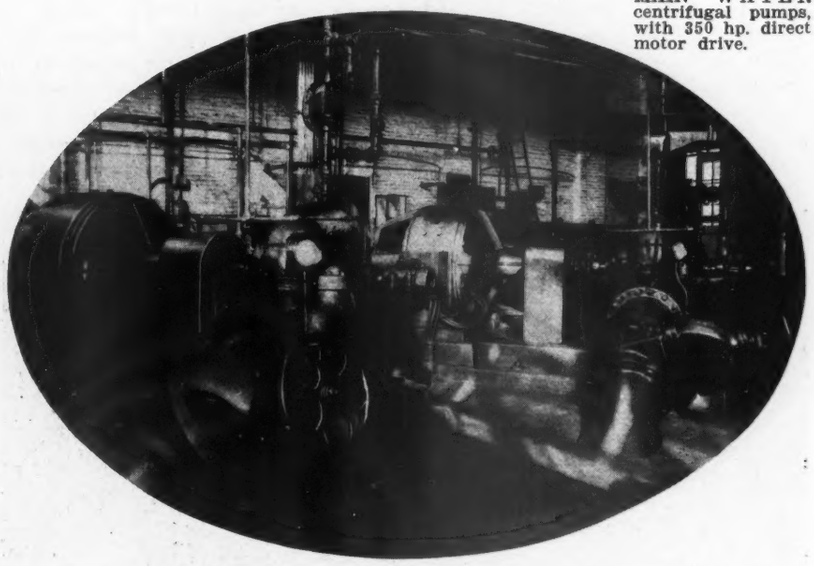
The original centrifugal machines used for raw sugar were driven from a line shaft by a clutch pulley and quarter-turn belt running over an idler pulley. There was a continuous line of these machines on close centers and the problem of adequately guarding these belts without seriously affecting operating conditions was not easily solved.

The new centrifugal machines for raw sugar are individually driven by motors mounted vertically above the centrifugal and connected to the spindle by an automatic friction clutch actuated by centrifugal force. These machines were erected in a new building which was of smaller size than would have been possible had the old belt-driven machines been used.

and MAINTENANCE POWER DRIVES

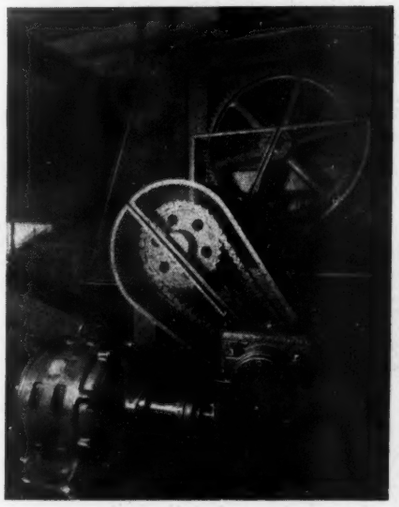
By H. H. DALTON
Power Engineer,
American Sugar Refining Company,
Brooklyn, N. Y.

MAIN WATER centrifugal pumps, with 350 hp. direct motor drive.



The new centrifugal machines for remelt sugar are slightly smaller than those for raw sugar and the motor is connected directly to the machine spindle without the use of a clutch. These machines were erected in an existing building, but here again the absence of belts allowed a most satisfactory layout in a space which it would have been impossible to use with belted machines.

Where a reduction in speed was required and a straight line drive was desirable, Jones speed reducers were used, and under similar conditions where a right angle drive was desirable, Cleveland worm gear drives are mounted on a common baseplate and the motor connected to the reducer by a flexible coupling. In some cases the reducer is connected directly to the machine by a flexible coupling, but in many instances it was desirable, due to the location of the supporting steel, to drive the machine from the reducer by a steel roller chain running on steel sprockets.

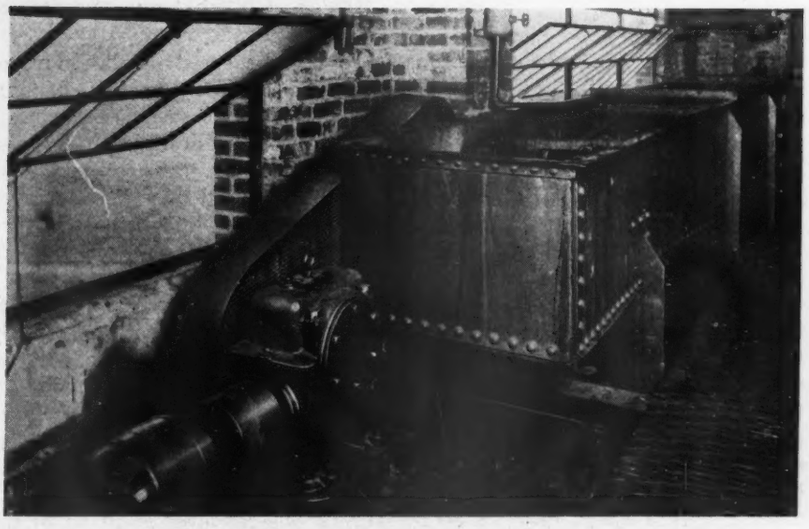


A MODERATE ratio worm speed reducer driving a raw sugar elevator through a finished steel roller chain.

* * *

Each of the raw sugar elevators supplying sugar to the minglers is driven by a 15-hp. 1,160-r.p.m. motor mounted on the same baseplate as a number 300 A. H. Cleveland worm gear reducer and connected to it by a Francke flexible coupling. The ratio of the reducer is 19½ to 1. A roller chain connects the reducer with the pinion shaft of the elevator. The coupling, chain and elevator head gears are protected by guards as required by the New York laws, but these are small compared to those that were required for the old belt drives that they replaced.

The raw sugar minglers are each driven by a 40-hp. 690-r.p.m. motor were installed. These cleanly, compact, efficient, perfectly lubricated, dustproof reducers have replaced the multiple belt and shafting drives throughout the refinery, and the improved appearance is striking. The cost of a reducer of this type is often less than the belting, pulleys, shafting, hangers and safety guards that it replaces.



THIS VIEW of one of the lint-catcher drives shows the compactness of an installation giving a total reduction of 160 to 1.

In all cases the motor and reducer

mounted on the same bedplate as a Jones spur gear speed reducer and connected to it by a Francke flexible coupling. The ratio of the reducer is 16 to 1. This is a straight line installation and the reducer is connected directly to the mingler shaft by a Francke coupling. A pair of rolls located directly over the mingler is driven from the mingler shaft by a roller chain running on steel sprockets. Coupling guards and a guard for the auxiliary chain drive are all that are required.

The vertical agitating shafts of the melting pans are driven by A. & F. Brown worm drives with ratios of 30 to 1. The worm casing is supported on channels spanning the mixer and the vertical thrust is taken up in a specially designed ball bearing mounted on the worm casing. The reducers are chain driven from a motor driven line shaft. This compact mechanism replaced the original cumbersome bevel gear belt-driven arrangement.

The drives for the lint catchers are typical examples of the methods used to get a large reduction of speed in a small space. Each catcher is driven by a 2-hp. 1,150-r.p.m. motor, mounted as usual on the same baseplate as a Cleveland worm gear reducer with a speed ratio of 80 to 1 and connected to it by a Francke coupling. The chain drive from the reducer to the catcher gives a further reduction of 2 to 1. A coupling guard and a chain guard give perfect protection. This drive is located at the end of the catcher close to a wall and occupies a floor space of less than six square feet.

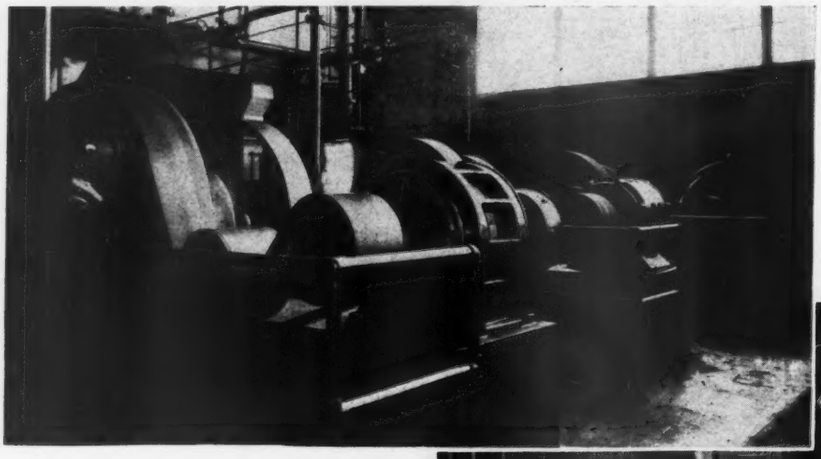
Practically all of the scroll and belt conveyors throughout the refinery are individually driven by motor and worm gear reducer units, the reducer delivering power to the conveyor through steel sprockets and a steel roller chain. The use of the sprockets and chain drive provides a very simple and cheap method of changing the speed of the conveyor over a fairly wide range, by changing the sprockets, if such speed change ever becomes desirable. It also allows the same ratio of speed reducer to be used over a wide range of applications by getting further speed changes in the selection of sprockets.

In two instances where one scroll delivers sugar to another, directly below it, the secondary shaft of the worm gear reducer is extended on both ends and each end equipped with a sprocket; each sprocket drives a conveyor. In many cases where there are a number of small conveyors, one conveyor is driven by the other, the power being transmitted from the motor and reducer through a special heavy scroll in the first conveyor. Where the power required is small or where the scrolls both belong to the same manufacturing unit and it is desirable to synchronize their operation, this method is very satisfactory. It eliminates line shafting or the use of a number of small motors and reducers and thereby lowers the first cost. A large motor in place of a number of small ones has the further advantage of operating with a higher power factor, where alternating current is the source of motive power.

Two of the air compressors are driven by synchronous motors and two by induction motors. Each motor is connected to its compressor by a Lenix short-center belt drive. This drive was selected as best meeting the requirements of speed ratio, quietness, floor space, and particularly as providing the cushioning effect on the motor so desirable when the air compressor governor unloads.

In the coal pulverizing room of the boiler house the pulverizing mills are driven by direct-connected, totally inclosed, dustproof motors. The circulating air for cooling the motors is taken from and delivered outside of the pulverizing room.

In any manufacturing plant cleanliness is essential to good workmanship. In a plant manufacturing a food product it is imperative that absolute cleanliness be maintained in every department and in every detail and in the remodeling program of this plant, one of the five refineries producing Domino Sugars, the same careful consideration of cleanliness was observed in the selection of the power drives as in the design and selection of the other equipment.



THE AIR compressors are driven by means of belts, on short centers, with modern, scientifically designed automatic idlers.

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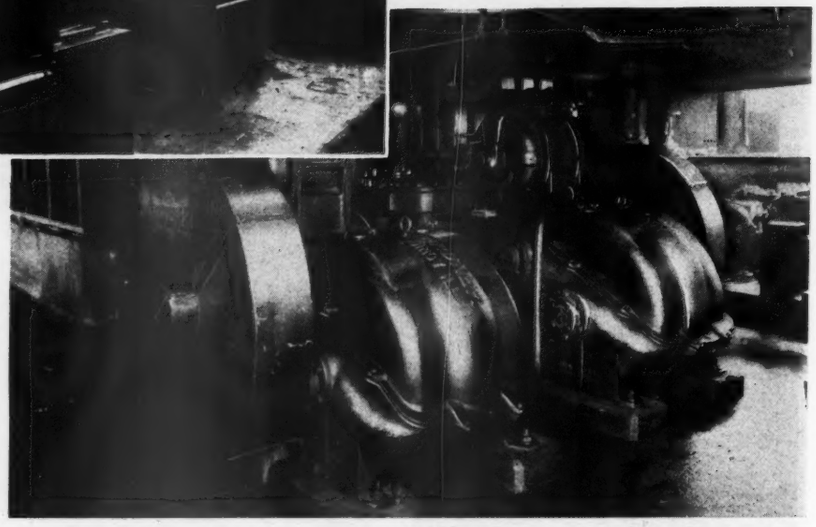
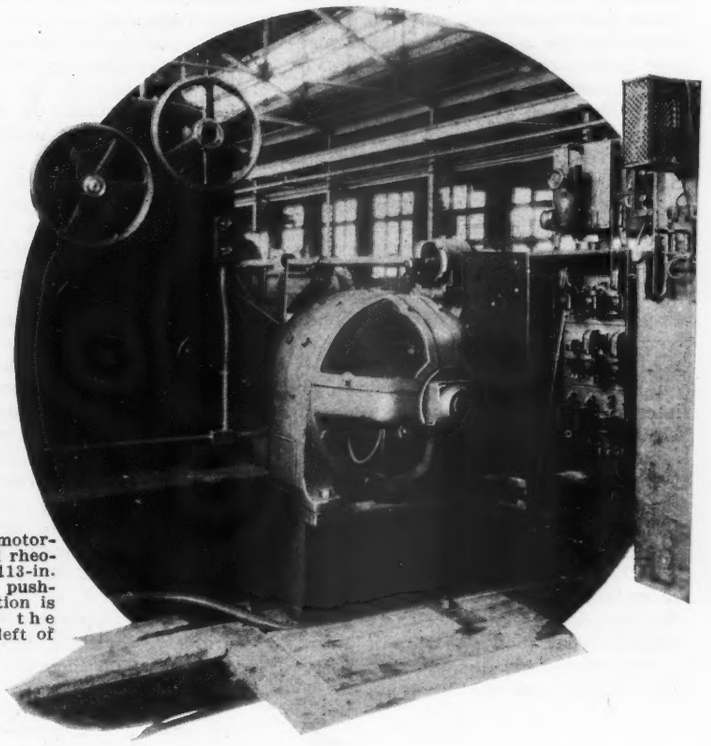


THE MOTORS are mounted directly on top of these reciprocating pumps which handle heavy syrup.

* * *

WHAT TYPE CONTROL *for* Industrial Power Drives?



Control with motor-operated field rheostat for a 113-in. lathe. The push-button station is mounted on the lathe, to the left of the motor.

WHEN THE SELECTION of a proper size and type of motor for a certain application is being considered, the question of the control to be used with it must always be kept in mind.

It is the function of control to supply desirable operating characteristics that have not been, or can not be, incorporated in the design of the motor. It must, therefore, provide a suitable means of starting and stopping the motor, giving the necessary protection against overload, low voltage, phase failure or reversal, and so on, and in many cases, provide for reversing the direction of rotation, and adjusting the speed.

Obviously, not all of these functions are needed or desirable for every application; hence, it becomes necessary to determine which of these or other functions are required under the service conditions and then select the equipment that will provide them in the most efficient manner.

In the following pages the different types of control and the methods employed in providing the functions desired will be discussed briefly.

H. H. WATSON, *Industrial Control Engineering Department, General Electric Company, Schenectady, N. Y.*—A natural classification that covers all industrial control devices is one based on the relationship between operator and machine. The two divisions of this grouping are manual and magnetic. Manual devices are those in which the basic functions are accomplished by some human agency or its equivalent. In magnetic controllers the basic functions are performed by electro-magnetic methods. The operation of magnetic controllers may be directed by human energy, or else these controllers may be made to function entirely independently of any operator, giving full automatic operation. The dividing line between manual and magnetic is not a distinct one, and there are a considerable number of "semi-magnetic" controllers.

One of the prime functions of industrial control is the regulation of the rate of acceleration of motors. With manual control, acceleration is at the will of the operator. Too rapid acceleration creates excessive stresses in the connected load, high current in the line and injurious stresses in the motor. Conversely, an over-cautious operator who moves a dial switch too slowly causes over-heated resistors, loss of electrical energy, and a waste of time.

Magnetic control requires only that it be set in motion from a push-button station, a float switch or other kind of master switch. The correct speed of acceleration is then automatically established. There have been a number of different methods used to give this automatic characteristic. The present tendency is to cause each event in the starting sequence to occur at some definitely predetermined time by means of timing relays which are both simple and reliable in operation.

Considering the application of control to motors, squirrel-cage motors constitute the largest single group of motors and consequently there is a diversity of controllers available for these motors. The simplest and most desirable method of starting squirrel-cage motors is to throw them directly on the line. Practically all general-purpose motors of this type are now built to withstand the stress incidental to this method of starting so that the limitations are those imposed by the power supply or the motor load. Standard squirrel-cage motors have inrush currents of from five to eight times full-load current with values of starting torque varying from 150 to 250 per cent.

The high-resistance rotor motor takes about four times full load current at standstill and develops about 350 per cent starting torque as an average.

Wherever the connected load cannot stand these values of torque and where the current indicated above exceeds the capacity of the power supply, full-voltage starting cannot be used; these limitations, however, are surprisingly few, and the advantages of simplicity, cheapness, compactness and so on found in across-the-line starters can be realized in a great number of motor applications.

Reduced torque and reduced inrush current are obtained by using either the hand or automatic compensator, which applies reduced voltage from an autotransformer to the motor terminals on the starting point and then connects the motor to the line in the running position. There are likewise a number of different types of starters which introduce one or more divisions of resistance

or reactance in the line to reduce the inrush current on starting.

Slip-ring or wound-rotor induction motors require two distinct operations for starting. The stator is connected to the power supply and the rotor starting resistance is short circuited step by step. Those two operations can be accomplished by the use of either hand-operated devices or magnetic contactors, or by combinations of these. For example, a very common type of starter for a centrifugal pump driven by a 2,300-volt, slipring motor is a hand-operated oil circuit breaker for the primary and magnetic contactors for automatically accelerating the motor.

Variable speeds are obtainable from slipring induction motors by adjusting the amount of resistance in the rotor circuit. A drum switch or contactors controlled from a master switch are used to obtain this adjustment.

The slipring motor is reversed by interchanging two of the stator leads. Drum switches which include means for accomplishing this are frequently used. Contactors mechanically interlocked give the same operation for magnetic control. Plugging is an added feature available when the equipment is reversible. While rotating in the forward direction, the application of power in the opposite direction acts as a positive brake to slow down the motor quickly.

Between standstill and rated speed the synchronous motor is in effect a squirrel-cage induction motor and is started by either the across-the-line or the reduced-voltage methods. In addition to this procedure, the d.c. field winding must be excited after the motor has attained approximately rated speed. The manual device furnished for this operation is a quick make-and-break, hand-operated switch. The completely automatic starter uses relays which apply field at the proper time.

The dial switch which cuts out starting resistance as it is rotated was one of the earliest forms of controller for d.c. motors. The same device with a few refinements is still the standard manual starter for small d.c. motors. Large motors are often controlled from drum switches, which may include reversing connections. Braking can be accomplished by reversing the power supply (plugging), or by allowing the motor to act as a generator loaded on a resistance (dynamic braking). All of the functions of the manual controllers are available in magnetic devices, which are rapidly replacing manual controllers.

Speed control can always be obtained by adjusting the resistance in the motor armature circuit. This method introduces power losses and the speed varies with the load. The more desirable method of speed control is to use an adjustable-speed motor and control the speed with a field rheostat.

The most important development in industrial control engineering in the past few years is the temperature overload relay. The maximum output of any motor is the load which it will carry without overheating. Thermal overload relays employ heating, elements which carry the line current, or current proportional to the line current, and some device which is responsive to temperature.

There are applications where it is desirable to limit the maximum amount of current and hence the maximum torque. For example, instantaneous overload relays are used to protect rock crushers when the jaws become jammed on "tramp iron" by instantly causing the motor line circuit to be opened. Also, the commutators of d.c. steel mill auxiliary motors are protected from arc-over caused by stalled rolls, by relays which instantly cut off the power to the motor.

Again, it is quite essential in many a.c. motor applications that a reversal of the motor must not occur as a result of an accidental reversal of the power supply. Phase reversal relays which open up the control circuit of the starter instantly when a phase reversal occurs, afford this insurance.

Upon the occasion of voltage failure it is nearly always imperative that machinery does not restart upon the return of voltage. Workmen taking advantage of a shut-down may be engaged in oiling gearing or adjusting tools, and an unannounced restart would result in serious injury. Manual controllers are often equipped with a no-voltage release which returns the operating handle to the off position, or else requires a deliberate action by the operator to restart the motor. The same feature is usually a part of magnetic control.

Control may however, be made automatic so that, as in ventilating systems, the controller automatically restarts the motor on return of voltage. Thus there is no greater delay than the actual period of voltage failure.

G. H. WHITTINGHAM, *Chief Engineer, Monitor Controller Company, Baltimore, Md.* — Complete control of an electric motor involves the following functions: starting, stopping, reversing, and speed change, which may be combined in any desired way to establish a definite program of operation.

If the normal current taken by a motor when startng it not enough to create serious line disturbances, the automatic starter is reduced to its simplest form because its only function is to close a switch and furnish protection from overload and low voltage.

An across-the-line starter of this type is shown on page 589. It is designed for operating squirrel-cage and self-starting induction motors equipped with an internal starting resistor that is thown out by a centrifugal switch as the motor approaches full speed.

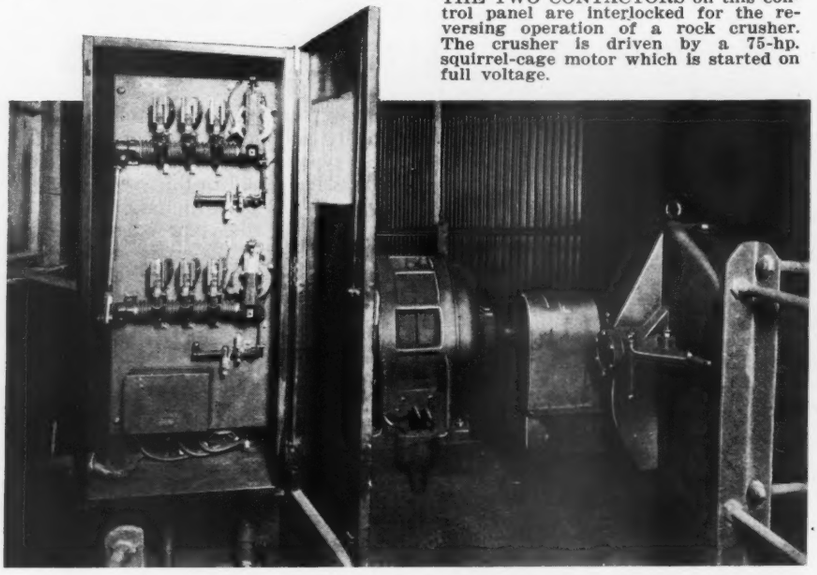
All other functions have to do with safety. For instance, excessive overloads must trip out the motor quickly and slight overloads, when prolonged, must trip it out before any damage can result from overheating. This requires dalayed action or inverse time element action of the overload protective device.

In the starter mentioned above, delayed action is obtained by using heat generated by the motor current to operate a relay that in turn cuts off the excitation of the main contactor.

If the relay is so designed that it returns to closed position when the coil cools off, it is called "automatic reset" and can be used with any starter operated by momentary contact control stations. Of course, the motor will not start until the start button is pushed.

To provide protection with this device for motors operated by maintained-contact stations where the starting switch is left closed while running, the relay must stay open until voluntarily reset. This relay is called manual reset.

If the voltage drops too low or fails altogether, the motor will stop and should be disconnected from the line so that when power comes back it will not start up automatically. The contactor lends itself inherently to this protection

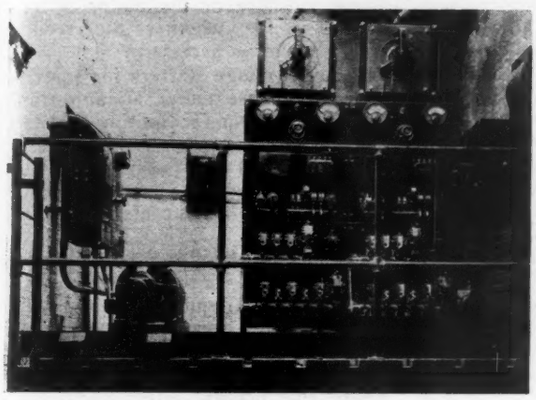


THE TWO CONTACTORS on this control panel are interlocked for the reversing operation of a rock crusher. The crusher is driven by a 75-hp. squirrel-cage motor which is started on full voltage.

and if equipped with a pick-up which opens the coil when the contactor is open, low-voltage protection is assured.

When the motor current rush is so great as to product intolerable line disturbances, resistance must be connected in the circuit during the starting period: in alternating-current circuits a special-type transformer may also be used.

The manner of connecting this resistance depends upon the type of motor.



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THESE ARE the magnetic control panels for two 145-hp. synchronous motors. Here the use of push button control resulted in a desirable saving in floor space as the control panels are mounted in an overhead gallery that was previously unused.

* * * *

Direct-current motors have starting resistance connected in the motor leads. Resistance may be connected in the leads of squirrel-cage motors, or an auto-transformer (compensator) is used. Wound rotor motors, such as the slip-ring induction and Fynn-Weichsel, have resistance connected in the secondary winding.

In general, there are three ways of accelerating motors with resistance-type starters:

1. Counter emf.
2. Current limit.
3. Time limit.

The counter-emf. method uses contactors to cut out successive steps of series resistance, each contactor being adjusted to close when the voltage across the motor armature reaches a certain value. This method has certain disadvantages that limits its use, for the most part, to small motors.

Overload and low-voltage protection with the counter-emf. starter is no different than with any other.

The current-limit method of starting is generally used in direct-current operation except where the load picks up faster than the speed as in the case of centrifugal pumps.

The successive steps of resistance in the current-limit starter are cut out by contactors that close as the current to the motor decreases, each contactor being set to close at a definite maximum current. One form of current-limit starter is shown on page 590.

Overload and low-voltage protection are provided in the usual manner.

The time limit starter is used with d.c. motors having a load characteristic that is unsuited to current limit control. Time limit control is also best suited for use with a.c. motors. There are various methods of assuring a time interval between the closing of the contactors controlling the successive steps of resistance.

The dashpot, which consists of a piston working against either air or liquid pressure is the oldest practical device for delaying switch action.

Timing may be done by a pilot motor either electric or clockwork. The electric motor presupposes constant voltage, with direct current, and constant frequency with alternating current.

A thermal relay utilizing the heating effect of a current supplied by a constant-voltage source is a reliable timing device except that its period is affected to an objectionable degree by the room temperature unless the heater is operated at a fairly high temperature.

By compensating the thermal relay for room temperature changes we can operate at low temperature. Then the heating element can be made of low resistance, affording a very simple and accurate timing device for constant-voltage circuits.

Ordinarily, the load of the motor will stop it quickly enough when the power is shut off, but there are cases where a quick stop is important either for speeding up production or for safety. Also there are applications in which accurate stops must be made as a part of the working cycle of the machine.

Of course, there are various types of brakes that may be applied but this discussion will be confined to electrical braking of which there are two types: dynamic and reverse power.

Dynamic braking is usually applied to d.c. motors because it gives a quick, smooth stop and if zero-temperature-co-efficient resistors are used, it gives an accurate stop. By this method the momentum of the motor and the machine it drives is absorbed by driving the motor as a generator and dissipating the power in a resistor that is connected across the armature of the motor. The braking power is always proportional to the need for it and disappears entirely when the motor is at rest. Therefore, if a motor is to be held stationary while at rest, some mechanical brake must be used in addition to the dynamic brake.

A d.c. controller equipped with dynamic break is shown on page 587. The opening of the main contactor closes a switch which connects a resistor directly across the armature. The rate of braking is determined by the resistance. The less the resistance, the greater the braking power.

Reverse-power brakes are used in both a.c. and d.c. installations where extra-quick stops are required, as in reversing operations. In the reverse-power method the momentum of the motor and of the machine it drives is pitted against the power of the line connected so as to reverse the motor.

With this method the braking power is continuous and does not decrease as the motor slows up. Therefore, it stops the motor in the shortest possible time and the power must be cut off at the moment the motor stops; otherwise it will reversee the rotation and run the motor in the opposit direction.

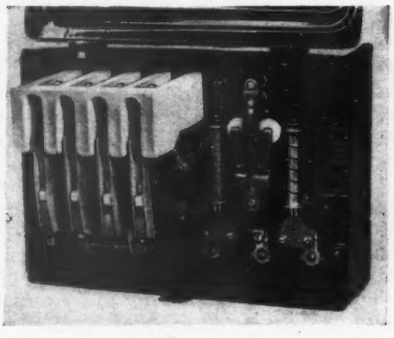
The automatic reversing of either a.c. or d.c. motors involves the reversal of two of the leads. The usual way of doing this is to use two separate main contactors interlocked either mechanically or electrically so that only one can be closed at the same time.

The control of motor speed is such a big subject, that only a few of the more usualy systems can be mentioned here.

First of all, speed control depends upon the type of motor. Series or varying-speed d.c. motors are usually controlled by resistance in series with the main leads. Shunt or compound motors may be controlled by varying the shunt field, by series resistance and by resistance across the armature.

Squirrel-cage motors, unless equipped with special windings, cannot have their speed varied. The slipring motor is generally employed in industrial applications where speed changes are necessary and direct current is not available. Slipring motors are controlled by varying the resistance of the secondary, or rotor circuit.

In every case, so far as the controller is concerned, speed variation means



AN ACROSS-THE-LINE starter for three-phase, squirrel-cage motors. Overload protection is provided by the two spiral expansion elements at the right, which twist sufficiently at a certain temperature to open the control circuit and stop the motor.

* * * *

manipulation of resistance in some circuit. The complication comes in when the speed must be varied over a wide range and safety must be provided under all conditions. The first requirement, in many cases, is the ability to set the running speed and then start and stop the motor whenever required without disturbing the speed setting of the control rheostat.

To assure this precaution, the type of pre-set speed controller shown on page 587 was developed. In this controller the accelerating contactors hold a short circuit across the speed-setting rheostat until the motor is at normal speed and then it is released, allowing the motor to speed up to its pre-set working value, as set by the rheostat in the field circuit.

Whether speed is changed by altering the connections to the windings, by changing the voltage, or by varying resistance in one or more circuits, a switch is required to open and close circuits in the proper sequence. Therefore, control, so far as the controller is concerned, boils down to the mechanism for the operation of switches at the proper time with reference to the working cycle, economy, safety and convenience.

In many cases, it is required that the operator be able to slow down the motor by pushing a button and run at very slow speed, or perhaps run and stop at short intervals (inching).

In this case the speed rheostat or other arrangement that gives the desired slow speed, is connected with contactors so that when the slow button is pressed, all other speed connections are annulled and the slow-speed connection made.

Such a list might be expanded to great length, as an almost endless variety of operating conditions and requirements are found in industrial applications. However, by combining the various elements described above in connection with the elementary operations of motor speed control, complete working cycles with definite timing can be set up and a controller produced that will put a motor through any series of operations it is capable of executing.

H. D. JAMES, *Consulting Control Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.*—The question of when to use manual and when to use magnetic control is sometimes a puzzling one. In any case it is something that merits careful consideration.

The term manual control usually means a controller having all of its basic functions performed manually, such as, opening and closing the electrical connections to the motor and short-circuiting the resistor in the armature circuit.

The manual controller has some distinct advantages, namely:

1. The first cost is usually less than for the magnetic type.
2. It has fewer electrical connections, so that it is easier to understand.
3. In many cases it is smaller and, therefore, easier to mount.
4. Its operation does not depend upon the completion of electrical connections through pilot circuits or the proper performance of magnets.
5. It is not so likely to be adversely affected by wide variation in line voltage.

On the other hand manual control is not well suited for a complicated sequence of operations and, when used for large motors, it often requires considerable effort to operate. Other limitations are:

1. The location must be accessible to the operator. This may require running the main electrical connections a considerable distance.
2. The hazard to the operator is increased, as the main source of power is located close to his hand.
3. It is difficult to provide for overload and low-voltage protection in some types of control.
4. The manipulation depends upon the operator. It requires more skill and judgment to operate a manual controller than a magnetic controller where the basic functions are automatic.
5. The operator may leave the handle on one of the starting notches and burn up the resistor unless special arrangements are made to avoid this difficulty.

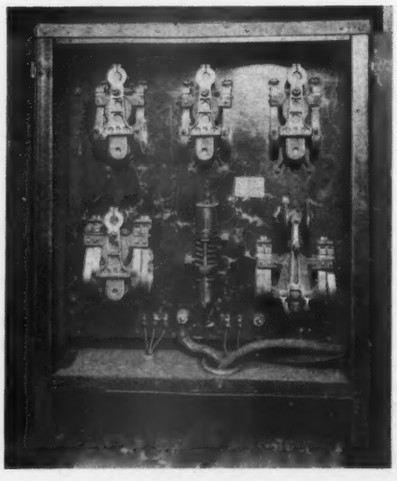
The most common use of manual control is to start motors. We are all familiar with the direct-current starting rheostat consisting of a faceplate with contacts connected to the starting resistor and an arm sliding over these contacts.

The squirrel-cage induction motor is the type most commonly used. Small sizes of this motor can be started by connecting to full voltage. When a knife switch is used as a starter, the motor is protected from overload by thermal cutouts. If the switch is biased to the open position by a spring and held closed by a magnet a thermal overload relay is used to protect against overload. This latter arrangement also provides low-voltage protection, as the switch opens automatically on failure of power.

The ordinary form of knife switch should not be used to control motors where the unexpected starting of the motor after power failure would introduce a personal hazard or cause damage to the driven machinery. Most equipment requires this protection; so the ordinary knife switch with cutouts has a limited application.

* * * *

IN THIS CURRENT-LIMIT starter the upper coil of each contactor is connected across the line. The lower coil is in series with the motor and opposes the tendency of the upper coil to close the contactor until the motor current drops. Then the contactor closes, cutting out the corresponding step of resistance.



Large squirrel-cage motors require some form of reduced voltage starter to limit the current taken at the time of starting. The local power company has rules specifying the amount of current inrush which may be taken when starting different sizes of motors so that the design and size of the motor selected will determine whether the reduced voltage starter is necessary.

Reduced-voltage starters for squirrel-cage motors use either an auto-transformer or resistor for limiting the starting current. In a few instances an impedance coil has been used. The manual started of this type usually has the off position in the center of the handle movement.

The drum controller has held its own in competition with the magnetic control when used for regulating the speed of motors, largely because it is more compact and easier to handle. The principal limitation is for large motors where the manual effort required to operate the controller becomes a limiting factor. This is particularly true for cranes and hoists that require the continual operation of the controller throughout the working day. The drum controller does not provide for overload or low-voltage protection, in itself. These features are usually provided by a protective panel consisting of one or more magnetic contactors with overload relays. Also, a circuit breaker provided with overload and low voltage release may be used for this purpose.

For crane and hoist applications drum controllers are successfully used up to 50-hp. rating, and sometimes for larger motors where the operation is infrequent. Drum controllers are used in the secondary circuit of wound-rotor induction motors for speed regulation. The most common applications are: fans, air compressors and refrigerating machinery.

If the motor is large, its primary circuit is controlled by magnet contactors or a circuit breaker. These applications require infrequent operation of the controller so that the force required to manipulate it is not a limiting factor.

Improvements in magnetic control have materially reduced its first cost and size and have increased its reliability so that push-button starters are more often used than manual starters on account of their greater convenience both in installation and operation. The magnet controller is also safer for persons using it. In many cases magnetic control can be located to so much better advantage than manual control that the increased cost of the controller itself is largely compensated for by the reduced cost of installation.

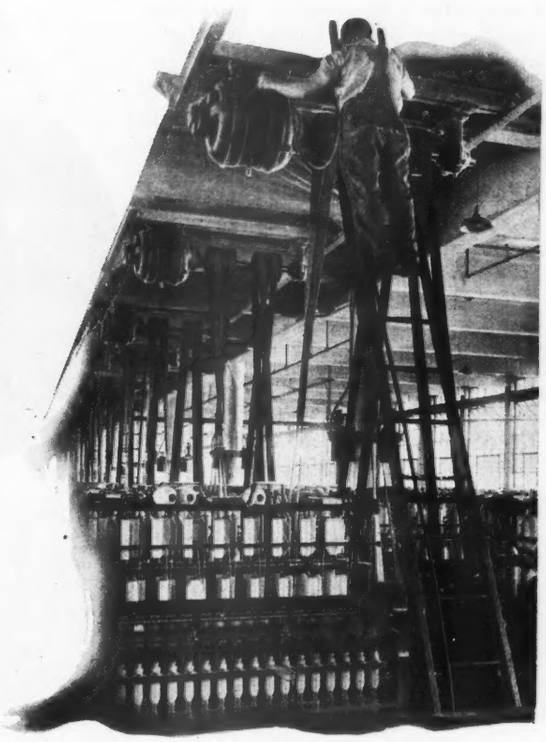
Manual control is usually less expensive where speed regulation is required, particularly if a large number of operating points are necessary. For starting and reversing motors, magnetic control is more generally used.

SYSTEMATIC MAINTENANCE

Keeps Motor Upkeep Down

By FRANK P. COOK

Operating Engineer
and
Chief Electrician,
Naumkeag Steam Cotton Company
Salem, Mass.



SYSTEMATIC cleaning with compressed air is a good antedote for dusts that cause most of the winding failures.

TWO CENTS is not a great deal of money to the average person today. In most places, it will not pay the tax on a gallon of gas. It will not buy admission to the movies, neither will it purchase your favorite magazine, nevertheless, when it comes to church, or to matters pertaining to industrial plant operation where the unit is applied to thousands of involved drives—it is *big* money.

Most of us scorn to mention the difference a few cents make, but for the sum of two cents, momentous decisions affecting human conduct have been made. Throughout the English speaking world, two cents is usually the maximum price quoted for an overt act, and not a few of us realize only after it is too late that the money consideration should have been left out of the argument. It is human nature to be weak, also careless with money especially if it is being spent for someone else.

In plant operation, that sum added to the purchase price of an object is inconsequential, but where thousands of such objects are represented in the order there is bound to be a notable difference in the total price. Likewise, in plant maintenance work where more than just a few drives are employed, the total cost becomes a matter of deep concern. Since the success or failure of many industries is dependent upon even smaller margins per unit, it represents after all, a sum that cannot be ignored, whether it is used in connection with outgo or income.

In this case the sum is used in connection with the outgo, that is maintenance expenditure, but only that portion that has to do with the repair of the plant equipment, consisting of the electrical and mechanical elements of power transmission.

The plant wherein low-cost motor repair is featured, is that of the Naumkeag Steam Cotton Company, located at Salem, Mass., in which 4,902 motors and control equipments are now in actual continual service, 48 hr. per week, every week in the year and occasionally 55 hr. night work per week additional at various seasons of the year.

The story goes back, however, to the period between 1916 and 1927, when the average number of drive equipments in service on a 48-hr. week basis amounted to 3,200. This figure was determined as follows: At the end of 1916 there were 2,600 drive units in operation and 4,000 by the end of 1926. From 1922 to 1926 (four years) the plant was operating a 55-hr. night shift on from 500 to 700 drives and 2,900 on a 48-hr. per week day-shift, schedule the equivalent of which being 3,900 drive units in service on a 48-hr. week basis. Then the average number of drive units in service over the total 11-year period on a 48-hr. basis would be practically 3,200.

Since that time, however, the total number of drive units has increased to 4,902 representing in all, 9,819 connected horsepower, varying in capacity from 1/20 to 220 hp. as shown by the accompanying table.

Hp.	No.	Hp.	No.	Hp.	No.
1/20	1	1½	12	35	1
1/12	1	2	10	40	1
¼	144	3	19	50	5
⅓	11	5	155	75	1
½	1,554	7½	195	100	2
⅝	1	10	53	125	2
¾	2,542	15	72	150	1
1	13	20	2	220	1
1¼	13	25	75	Misc.	15
Total hp					9,819
Total No.					4,902

Any proportion of these totals, is, on the whole, representative of the average industrial plant and the

method employed in keeping down the cost of repairs and repair parts incidental thereto, is applicable to any plant.

Fact finding necessitates courage, especially if the facts are to be dug out of your own back yard, but with a sympathetic management, their only object is to know where, how and why the money is being spent, and how much. For instance, we found that the cost of cleaning certain equipment in overtime was far in excess of the cost to do the same cleaning with the equipment out of production, so we follow this method in our maintenance schedule whenever possible.

To say that there was no regular maintenance system in the beginning would be misstating a fact. There was, but it wasn't taken seriously, yet routine inspection, oiling and greasing, repairs and the like were accomplished in the course of a day's work. The maintenance personnel was engaged in all manner of work whether it was related directly or indirectly to maintenance problems. There was no division, however, between the strictly maintenance (operating) functions and those of repair, consequently a method had to be devised to separate them and to provide the desired information contained herein.

A certain amount of overhead labor is present in any plant so by a process of elimination the irreducible minimum in personnel was reached and for those a schedule was drawn up for cleaning, oiling, starting-up duty and daily labor incidental to the operation of this equipment.

Every motor in the plant was given a plant number different from its serial number and machine number. These locations are on record, known to attendants and anyone concerned with their operation. The attendants were then assigned specific duties in connection with the equipment maintenance schedule, as follows.

One man is in constant attendance in the spinning mill on 301 overhead motors ranging from 5 to 125 hp. in capacities and having ring oiling bearings, the majority of which being group drives through belts to two and four-frame equipment. Every motor receives more or less attention in the matter of lubrication at least every week.

Waste-packed bearings on 200, 5 and 7½ hp. individual drive motors on spinning frames are oiled every three months requiring 24 hr. actual elapsed time for each oiling, or 96 hr. per year.

Every three months waste-packed bearings on 4,000 loom motors of from ½ to ¾ hp. capacity and arranged for individual drive through gears, are oiled. Five men are engaged for a period of ten days (76 hr.) each quarter, or 1,520 hr. per year. Fifty-four motors in service as individual drives on cloth room equipment, opening room, drawing frames including 1¼-hp. card motors, all having waste-packed bearings are serviced in a corresponding period.

LUBRICATION is intended primarily to reduce resistance to motion, but unless it is effective, the attendant benefits will be offset by excessively high maintenance costs.

PERIODICAL testing insures correct performance of equipment in the up-to-date plant where repair costs are figured in cents per motor per year. Portable Esterline instruments mounted on a portable platform and equipped with long leads facilitate tests on these overhead motors to determine load conditions.

One man puts in 5½ hr. per week greasing the chain drives on 146 spinning frame motors. Other chain drives on 78 machines are greased weekly as well as miscellaneous bearings and shaftings. The motor-drive gears, cam and crank shaft gears on 4,000 motors are greased monthly by one man in seven days of 7½ hr. each, totalling 52½ hr. per month.

The cleaning schedule for all motors in service corresponds somewhat to the oiling schedule just described, for instance, ten large motors (2-125 hp., 2-100 hp., 4-50 hp., 1-25 hp., 1-35 hp.) are cleaned weekly. A daily cleaning is given to sixteen opening room motors, (8-10 hp., 6-7½ hp., 1-5 hp., 1-3 hp.) also fifty-seven picker room motors average a cleaning once a week, whereas 236 spinning frame motors receive their polishing on a monthly schedule.

Every Saturday morning miscellaneous motors, such as air compressors, Frigidaire and other important small drives receive the attention of the cleaners.

All switch rooms are cleaned each Saturady, other switch and transformer rooms receive attention when needed. One man is in constant attendance at the shop caring for storage batteries, m.g. sets, switchboards for timeclock, fire alarm, and tying-in machine, d.c. systems, also handling emergency calls and keeping records of the department and to oversee the distribution of men for various duties as required.

Since the plant is operated exclusively on purchased power there is a surcharge for exceeding the contracted maximum demand, consequently the 10 men engaged in the oiling and cleaning schedule just outlined serve as overseers in the two normal starting-up periods of the day. Group drives, air compressors, etc., are started in sequence to avoid undue high starting peaks and this requires ½ hr. per day for the whole crew. Thus, determining the actual time for strictly overhead maintenance work revealed that it cost us per year, $9,230 which otherwise

would have been included in the actual repair column on the ledger.

It looked like a big job in separating all other costs from just repair costs but setting up a system for a definite purpose and adhering strictly to it provided the necessary means to determine these actual repair costs on the large group of ½- and ¾-hp. motors for the period previously mentioned and which are itemized as follows:

13 motor rewinds (outside)	$318.57
7 motor coil repairs in the shop	35.00
1 new motor shaft	21.35
20 motor keyways welded and resplined	60.00
11 motor leads renewed	55.00
3 motor bearings replaced 1 motor end bell replaced 25 motor pinions replaced Repairing loose rotor bar, 6 starting switches, miscellaneous repairs to other switches and incidental items thereto	250.00
Total	$739.92

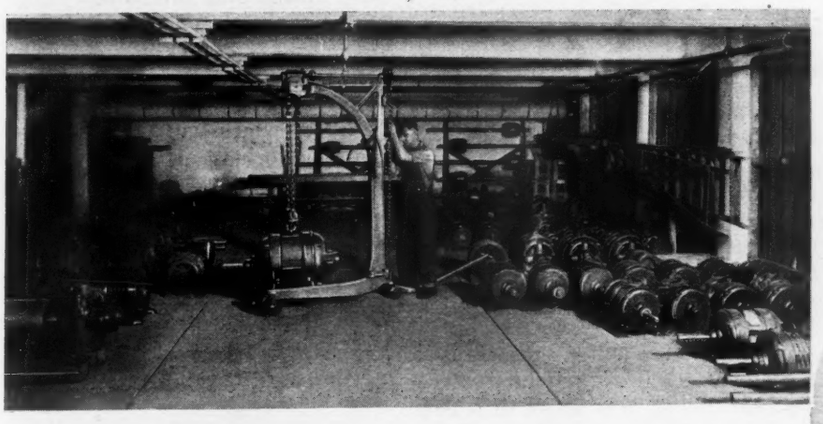
This total represented the actual money spent for the 11-yr. period during which the equivalent of 3,200 drives were in operation, therefore, the average cost for repairs amounted to 2.1 cents per motor.

That, however, is not the entire story because there are other factors that must be considered in the scheme of things to make such a showing possible, although in recent years due to changing conditions, age of equipment and the like, a new yardstick is to be used. The former method is to be replaced with a day-by-day record in segregating the monthly maintenance cost from "other" work which is directly chargeable to the equipment.

Under the monthly maintenance cost the following items will be checked against the specific drive equipment: labor of cleaning, oiling and greasing; repair cost for labor and material, ditto miscellaneous, and fuse renewal cost which you will note was not included previously. Entirely separate from the above will be lighting charges subdivided into labor, lamps, fuses and other material, thus giving a new set of values for comparison.

Some think that there is a great deal of irrelevant matter in connection with cost finding and no doubt there is, but it puts one behind the scenes where a man finds out what there is in the line of plant equipment and how it is used at the same time. For instance, there is the matter of spare equipment, interruptions to service, servicing equipment and stock room practices, all of which have some effect on the ultimate repair costs.

With the bearing linings that are made of special, hard metal, precautions are taken to store them properly which in this case consists of submerging them in a container of oil. Flaking and warping due to their exposure to the air is thus prevented. A lining that is damaged in storage to the extent that it cannot be used, increases the repair costs.



GOOD STORAGE facilities and proper handling of the equipment in storage as evidenced here insures the delivery of the equipment to the job in good operating condition. This is just another method of keeping upkeep down to the irriducible minimum.

Other spare parts, directly chargeable to capital investment are considered here, however, as insurance against expensive interruptions. The unanimity of opinion on this subject is evidenced by the number of spare motors that are kept on hand. Every motor, special or not has its counterpart in first-class, serviceable condition ready to bridge the gap in an emergency. A section of this storeroom is shown. Two compensators, one for starting duty up to 50 hp., the other for service up to 100 hp., are mounted on portable platforms which are taken to the place where trouble has developed. These compensators are completely wired with extra-long line and motor leads equipped with connectors for instant use on arrival. Little time is lost in delays with such equipment so available, and not because there is the spare part at hand, but due to the fact that there is supervision that brooks no delay.

With certain drives that require only fuse renewals in a shutdown the operator saves valuable time in sending for the repairman by pulling all fuses in the unit with the Trico insulated fuse pullers provided him, and then inserting all new fuses. No attempt is made to find the blown fuse or fuses at this time. When his supply of tested fuses is exhausted, the questionable fuses are exchanged for a new supply.

These questionable fuses are returned to and tested in the shop. The good fuses are returned to stock and a record is made of the number destroyed, all of which enters into repair cost data under the new system.

When the interruption is of a different nature than just fuses, the electrical department is notified by the machine operator who also advises the telephone operator at the main office, who fills out a slip as to time and machine. This slip is placed on the general manager's desk where it is kept until advice is received that the trouble has been cleared. As soon as practicable a yellow slip is forwarded to the general manager by the electrical department detailing the probable cause and remedy, and the length of time of stoppage.

The reason that certain maintenance men oversee the starting-up

SAFETY APPLIANCES employed for the purpose for which they were provided exert an influence on low maintenance costs in connection with wiring devices. Here Trico fuse pullers are used to prevent damage to the fuse blocks as well as injury to the operator who is shown renewing a set of blown fuses.

periods is that most equipment failures occur at this time. Where the motors are started by throwing them directly across the line, frequent failures are expected due to the inertia of high-speed machinery, although the mortality rate is not excessive.

When the emergency occurs as it often does with overhead motors, a special homemade rigging is brought into play that eliminates the need for scaffolding. It is worth describing because of its effectiveness for ceiling work. Four hooks made of 1½-in. T iron about 6 ft. long are slipped over the I-beam bearing supports. Two on each side of the motor. Side braces are fastened to the bottoms of these suspended hooks by means of thumb screws. Planks are laid on the outside making a stand for the repairman and leaving the well in the center clear for lowering and raising the equipment to be replaced. A small overhead trolley with a chain hoist is placed on the channel irons which support the motor, thereby permitting the removal of the motor with very little effort.

Every year the entire plant is shut down for a period of two weeks, during which all main buses are inspected for loose clamps, bolts, etc., and all necesasry repairs are made to the main primary and secondary switches. Poor contacts are corrected, the oil is changed or filtered, in fact, all equipment is placed in good operating condition and constant effort is made to keep it in service. Trouble is usually forestalled by routine testing such as the test that is shown being made on an overhead four-frame drive motor. It not only acquaints one with the drive conditions but it helps to mitigate the need for subsequent repair costs.

After all, repair costs are only relative because it is an item of expense that must be absorbed in any plant, but there is satisfaction in knowing that repair costs are for repairs only instead of for costs that cannot be accounted for otherwise.

Power Distribution

(Continued from page 547)

throughout and suspended from the ceiling with combination porcelain cleats and hangers.

Service is taken to the overhead motors through a starting box mounted on a column for the convenience of the operators. These boxes are Westinghouse 815 and 816 oil-circuit breakers for 7½-, and 15- and 25-hp. motors respectively. Where the motors are floor-mounted we employ the method of providing service as shown in the illustration on page 547. As explained, heretofore, the feeders are installed on the ceiling of the floor below.

In this installation, we provide disconnecting devices below the floor as well as above the floor for the protection of our electricians. Two motors are served from one circuit through a junction box with a conduit fitting which is supported on the floor. The conduit goes through the floor and the support, thereby, making the box and circuit waterproof as well as dustproof. Flexible leads extend from the junction box to the motors and their control devices which cover the gamut of practically every manufacturer of control equipment, some of which in the foreground may be recognized as G.E. and Westinghouse magnetic types, an E. C. & M. oil breaker and an I.C. air-brake auto-starter.

No definite standardization has been adopted because we are constantly taking advantage of the improved devices that are offered from time to time. This applies to equipment other than that engaged in the transfer of energy, and the statement is substantiated by the illustration on page 544 showing a super-safe distribution panel used throughout for lighting circuits. When we hear of any new device or a new method of drive, we are always willing to try it out, not that we intend to replace all of our existing equipment, but to be prepared for any improvement that might be obtained by its adoption at some future date. We believe, that every manufacturer has that much coming to him from the users of power transmission equipment. Every plant has the same facilities for co-operation of this kind that will tend to lift transmission from the slough of inactivity to a position where it may be recognized as a vital subject in industry.

In some respects the power distribution to our one-story building containing over 4,100 220-volt motors which vary in size from ¼ to 200 hp. is similar to the first installation except where the single-transformer station is used to serve the entire building. Here we have seven different towers containing the power and lighting transformers. The reason for these installations is due to the advantage that can be gained in saving copper and the resultant losses in handling a large block of power. Flexibility is obtained in a degree impossible in a single unit.

Lighting has been no easy problem but we benefit by our practice of maintaining balanced circuits. For intensity of illumination, it has been laid out in accordance with modern practice. All circuits are in conduit supported from the ceiling and controlled from distribution panels similar to the one shown in the accompanying illustration. As with our power circuits, lighting circuits are subdivided and so arranged that we have, we feel, the maximum that can be obtained for continuity of service.

Society Activities During National Power Show

COINCIDENT with the Seventh National Exposition of Power and Mechanical Engineering at the Grand Central Palace, New York, N. Y., Dec. 3 to 7 inclusive, will be the annual meetings of the American Society of Mechanical Engineers which will be held in the main auditorium of the Engineers Bldg. at 29 West 39th St., New York City.

A special session of the A.S.M.E. will be held Dec. 6 at 2 P.M. under the auspices of the Society for Electrical Development, Inc. to discuss Mechanical Methods of Handling Materials. Six papers have been prepared for this meeting.

The annual meeting of the Power Transmission Association will be held Dec. 6 at the Hotel Commodore.

The Power Show will act as a medium for establishing contacts with the users of power transmission equipment who will come from every section of the country for the purpose of observing the advances made in mechanical equipment. The power transmission equipment section will contain 110 exhibits where the most modern equipment will be shown. These exhibits will be under the supervision and direction of competent engineers who are prepared to diagnose the transmission problems of industry.

Last, but not least, *Industrial Engineering* will be represented at the show by the various editors. If you are going to be at the show stop at the McGraw-Shaw Company booth and pay us a visit; let's get acquainted.

NEW EQUIPMENT

For Plant Operation and Maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Floodlight Attachment

A FLOODLIGHT attachment of new design, for use with the familiar small tanks of dissolved acetylene, the same as are being used for truck and tractor lighting, has been announced by the Prest-O-Lite Company, Inc., 30 East 42nd Street, New York City.

The attachment, it is claimed, is of simple, strong, rigid, and compact construction. Universal adjustment is obtained with only one swing joint, thus minimizing the possibility of leakage. It is also said that because of the substantial construction of the new parts, and because of its position near the center line of the tank, the attachment itself can be used as a handle in carrying the entire unit.

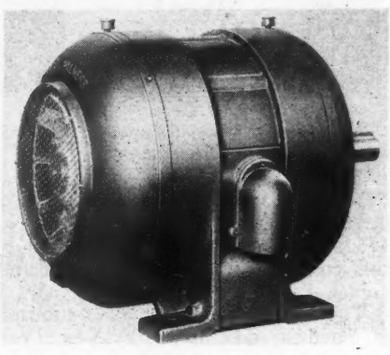
The reflector, which is 10 in. in diameter, can be taken off by removing a single knurled nut. A new type of burner is used which, it is claimed, will not carbon up." This burner is placed at a fixed focal point and requires no adjustment.

Prest-O-Light Floodlight Attachment

Inclosed Motor

A NEW line of totally inclosed, fan-cooled motors from 1 to 50 hp., have been developed by the Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

In this new design, all of the active parts, such as stator core, stator winding and the rotors, are completely inclosed, preventing contact of outside air, dirt, dust, fumes, moisture, etc., with the interior or active parts.



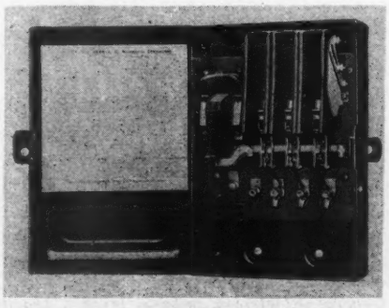
Allis-Chalmers Type ARZ Completely Inclosed Fan-Cooled Motor

Heat is carried away by a sufficient volume of cooling air thrust around and across those parts which conduct the heat from the interior to the outer surfaces. A circumferential air jacket controls the path of the cooling air. Solid cast iron bearing houses are attached to stator end heads with machined fit, which, with greased packed bearings, form a perfect end closure, the manufacturer states. Internal parts of the motor are accessible by the removal of the housing.

A.C. Magnetic Contactors

A NEW line of a.c. magnetic contactors, designed especially for controlling lighting and power circuits automatically, and for miscellaneous applications, has been announced by The Cutler-Hammer Manufacturing Company, Milwaukee, Wis.

The construction of these new contactors includes the very latest developments in contactor design, it is said. High efficiency hammer head type magnets with self-aligning armature, continuous duty magnet coil, hardened steel bushings, tin dipped solid copper contacts, magnetic blowouts and chimney type arc shields are some of the outstanding features. In addition, the large size contactors have the magnet frame supported on a spring plate which absorbs the shock of the magnet on closing.



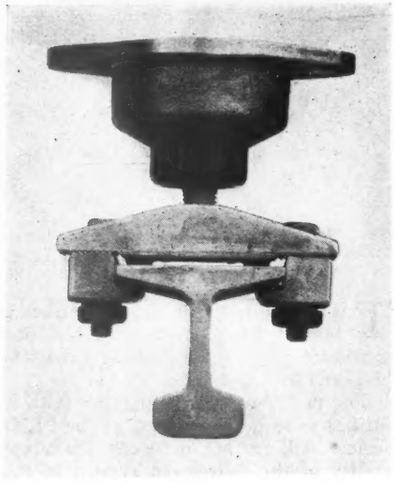
Cutler-Hammer A.C. Magnetic Contactor

Two- or three-wire control can be used. With two-wire control, low voltage release is provided and with three-wire control, low voltage protection is provided. A wide variety of types and sizes are available to fit any need. There are two-, three- and four-pole types, with an ampere capacity ranging from 20 to 150 amperes. The contactors are supplied mounted in a split enclosing case or on a slate panel for switchboard mounting.

Crane Rail Support

AN insulating unit, with which it is claimed it is practically impossible to drop a rail from any cause, has been announced by the Delta-Star Electric Company, 2400 Block Fulton St., Chicago, Ill.

The unit consists of a cup-shaped porcelain held in compression between an outside fitting and the mushroom head of the rail supporting bolt. The tension is distributed uniformly over the porcelain cup by washers on the outside of the cup. A molded insulating disk over the washer and bolt assembly, with a compound steel, protects the whole assembly from the instance of moisture, insuring a high dielectric value and cushioning the porcelain against abnormal impact.



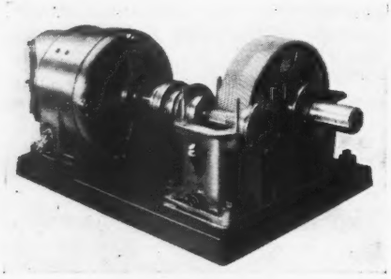
Delta-Star Electric Company Crane Rail Support

The lugs and clamp faces have notched surfaces fitting into each other. These notches are so spaced that by moving the lugs one notch in or out they fit the next size smaller or larger rail. The clamps adjust ½ in. up and down on the stud bolt, and are provided with a locking setscrew.

Speed Reducers

A NEW and complete series of speed reducers which have Sykes continuous herringbone gears and anti-friction bearings, has been announced by the Farrel-Birmingham Company, 344 Vulcan Street, Buffalo, N. Y.

Some of the improvements claimed for this new design of reducer are; the roller bearings being of the type which combine journal and thrust capacity, both pinion and gear shafts are held from end of float, and are therefore protected from abuse from connecting mechanism. The lubrication is simpler than with the plain bearing unit, since in all cases the same oil may be used for gears and bearings and the splash and flood automatic system of lubrication is possible throughout the whole series. The roller bearings being interchangeable, it is possible to make the gear units interchangeable, and to manufacture them in larger quantities than the plain bearing type unit, thereby reducing the initial cost. There is also a considerable saving in space.



Farrel-Birmingham Company, Inc., Herringbone Speed Reducer

Wiremold

THE addition of a new line of "Master Size" Wiremold has been announced by the Wiremold Company, of Hartford, Conn.

The new size, which together with its fittings is to be designated as the "1,000 series" still further increases the adaptability of the Wiremold system in factories, stores and office buildings and other installations of this nature.

According to the announcement, the "Master Size" Wiremold is designed for use with heavy duty industrial and commercial wiring circuits where ease of installation must be combined with absolute protection, safety and conformity to underwriters' requirements.

Sign Illuminator

A SIGN illuminator known as No. 165, comprising two sharp warning signals with a brightly illuminated enameled sign, has been introduced by The Nichols-Lintern Company, 7960 Lorain Avenue, Cleveland, Ohio.

The wording of the sign may be changed for the particular application, and lenses are obtainable having 2-, 3- or 4-in. diameters. This is a two-direction signal supplementing the No. 155 sign illuminator, manufactured by this company, which is a one-direction signal.

The Nichols-Lintern Company's No. 165 Sign Illuminator

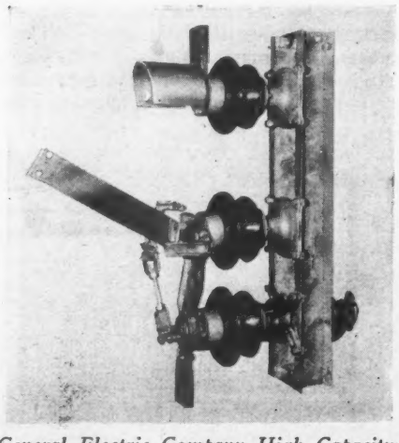
The lantern is of cast aluminum and is fitted to take two 10-in. by 14-in. enameled signs. It is claimed to be of very light weight and rugged in construction, and dust, vapor and weather proof. A hinged door at the bottom of the lantern makes lamp changes easy, but may be fitted to prevent the easy pilferage of lamps. The lenses used meet American Railway Association signal requirements, and may be fitted with hoods for daylight use.

Disconnecting Switch

A NEW high capacity disconnecting switch for group operation, in which the contact pressure is obtained independently from the movement of the blade, has been announced by the General Electric Company, Schenectady, N. Y.

The switch is designed in ratings of 2,000, 3,000 and 4,000 amperes, and for voltages of 7,500, 15,000 and 25,000 volts. It is known as the type RP-2. This switch is of the conventional vertical-break type, the blade being swung between the open and closed positions by a linkage operated by a revolving insulator.

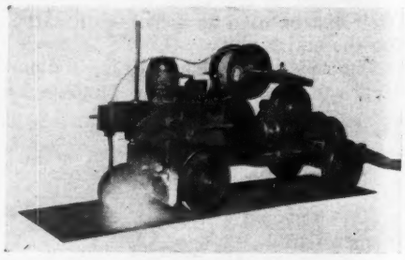
An entirely new method of securing high pressure contact is employed, however, which eliminates the heavy contact friction usually found in group-operated switches of the higher capacities, as well as the spring washers and flexible shunts commonly required at the hinge clip. The blade of the switch consists of two parallel copper bars between which there is a plunger with wedges at each end. When the plunger is moved forward by the action of the operating mechanism, the wedges force the blade outward against the contact block. Both wedging motion and blade motion are accomplished by a single turning of the operating handle.



General Electric Company High Capacity Disconnecting Switch

Automatic Welder

AN AUTOMATIC tractor-type arc welder utilizing the electronic tornado principle, and used for making lap welds and butt welds on large tank bottoms and roofs, large pipes, and on similar work, has been placed on the market by the Lincoln Electric Company, Cleveland, Ohio. According to the manufacturer, power is supplied through a flexible cable, and all that is necessary is to line up the machine over a seam to be welded and to start the arc; the electrode and fibrous autogenizer are set automatically as the tractor travels forward.



Automatic Tractor Type Electronic Tornado Welder

The chief advantages claimed for this machine are high welding speeds and smooth uniform welds. Speeds on ¼ in. lap joints varying from 50 to 75 ft. per hour are obtained.

Disk Sander

A NEW disk sander is now being supplied to the trade by the United States Electrical Tool Company, Cincinnati, Ohio.

According to the announcement of this tool, a fan cooled Universal motor operates the 9-in. disk at 3,600 r.p.m. under load, the most widely accepted speed for this work. Ball bearings of a favored make are used throughout.

Fine, medium and coarse sanding disks are furnished. Also 12 ft. of flexible rubber covered cable, a two-tree attachment plug, and an armored cable guard are furnished as regular equipment. Total weight of the machine is 12 lb.

Heavy-Duty Ceiling Switch

A HEAVY-DUTY ceiling pull switch, known as P & S 2309 has been put on the market by Pass & Seymour, Inc., Solvay Station, Syracuse, N. Y.

This switch, which is supplied with durable, heavy cord, has a rating of 10 amp., 125 volts, and is manufactured with a solid or slotted base.

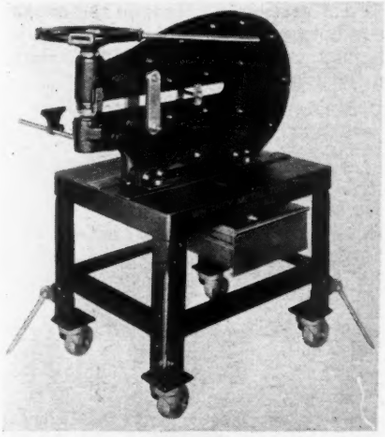
It is intended for use in controlling individually, commercial lighting units and units using high-wattage lamps in industrial plants, garages, stores, and so on.

Deep Throat Punch

A NEW model, known as Nos. 26 and 27, has been added to their line of punches by the Whitney Metal Tool Company, Rockford, Ill. According to the manufacturer, the main feature of this punch is the throat clearance. The No. 26 punch has an 18-in. throat depth; and the No. 27 has a 24-in. depth.

The frames of these punches are made by hot riveting two steel plates 1 in. thick together, in which is embodied the Whitney ball bearing spindle. The capacity of the No. 26 punch is a 2-in. hole through $\frac{3}{8}$-in. thickness of iron. The No. 27 will punch a 2-in. hole through 16-gage iron. Both machines are regularly equipped with side tie-rod plates, and when these plates are in position the machines have a capacity of $\frac{1}{2}$-in. hole through $\frac{3}{8}$-in. iron, with 7-in. throat clearance.

Handwheels are furnished with these machines. The manufacturer states that these handwheels are large enough for 80 per cent of the work without the use of a lever. A short lever, however, is furnishd with the equipment for punching heavy materials.



Whitney Metal Tool Company Deep Throat Punch

Paint Spray Gun

SEVERAL new additions to their paint spray gun have been announced by the Alexander Milburn Company, 1416-1428 West Baltimore St., Baltimore, Md.

Alexander Milburn Paint Spray Gun

These features are, first, a dial head which gives many different spray adjustments from a circular spray to a wider field than has hitherto been possible with spray guns it is claimed. The dialing permits the operator to obtain any desired spray instantly without first making tests. A series of indicator numerals have been added to the paint valve plunger. A pointer is operated as the operator turns the adjustment button. Just as the dial in the head produces the exact spray wanted, so the indicator numerals on the paint valve plunger provide the exact volume desired without the necessity of losing time by testing. The operator, having found that a certain class of work is best performed when the indicator points to a certain figure, makes the proper adjustment before beginning to spray.

The new Milburn spray gun is known as the type EF. To enable owners of the Milburn type E gun to obtain the benefit of the improvement, the new dialed air-control valve and the plunger have been made interchangeable and the type E can therefore be brought up to date by the insertion of these parts at the factory of the Alexander Milburn Company in Baltimore.

Expansible Tooth Sprocket

THERE has been developed by The Union Chain & Manufacturing Company, Sandusky, Ohio, a specially-designed sprocket, the teeth of which may be adjusted from time to time to accommodate the natural wear and elongation of the links of a chain. This elongation, although slight in any one link, is multiplied by the number of links in engagement with the sprocket, causing a jerky and noisy action.

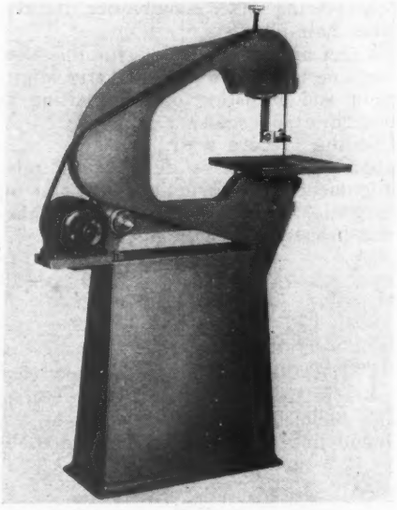
The sprocket is constructed with adjustable teeth of special design. Both sides of the body rim are machined to receive the teeth, which straddle and are firmly clamped to the rim. Turned bolts closely fitted in the rim project through elongated holes in the teeth, the latter being secured relatively to pitch diameter by means of square, bevel-edge adjusting blocks fitted between the lugs on the teeth. Holes are drilled through the blocks at four varying distances from the edges, and when the blocks are mounted on the bolts the pitch diameter of the sprocket is governed by the arrangement of the blocks.

As received the sprocket is correctly assembled to fit the chain. After the chain has elongated beyond a proper fit on the sprocket, the nuts are released and the eccentric blocks readjusted so as to expand the teeth to a next larger pitch diameter. This is usually required only a long intervals, as the wear and consequent elongation of the chain are greatly retarded by maintaining its proper fit on the sprocket.

Portable Band Saw

A PORTABLE band saw designed to give the power and handling capacity of a stationary machine, has been announced by the DeWalt Products Company, Leola, Pa.

According to the manufacturer, the unusual feature of using three tracking pulleys instead of two large pulleys to separate the two sections of a revolving saw blade, has made it possible to design a compact machine with a 20-in. clearance between the saw blade and the frame; and ability to handle material up to 7-in. in thickness.



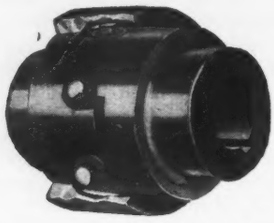
DeWalt Products Company Portable Band Saw

The machine is guarded to the maximum degree. The DeWalt Band Saw above-the-floor standard is mounted in one casting housing which covers the three tracking pulleys and the saw blade. By the simple means of one cover, hinged onto the casting, the blade is entirely covered, the only visible portion being at the cutting point.

The working table is 13$\frac{5}{8}$ in. square, and is equipped with a level indicator graduated in degrees. The table tilts 45 deg. to the right and 30 deg. to the left.

Flexible Couplings

A NEW coupling, known as the L. R. Coupling, is being offered by the Foote Bros. Gear and Machine Company, of Chicago, Illinois. The manufacturer states that this equipment is especially adaptable for use with small fractional horsepower motors.



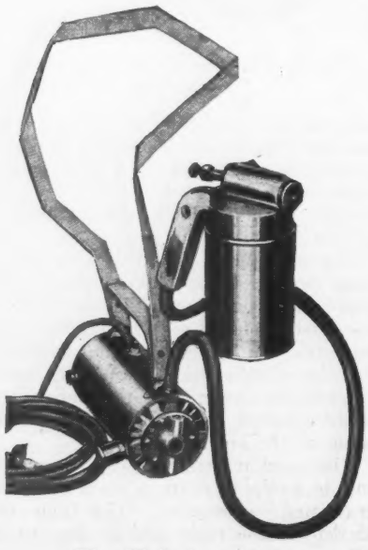
Foote Bros. Gear and Machine Company, L.R. Flexible Coupling

The new device is substantially a jaw coupling with radially disposed, loosely floating, resilient rollers, placed between jaws, which extend from the flanges parallel with the shafts. This, it is said, assures a rolling contact between them upon relative movement caused by either misalignment or end movement of the shaft of the power agency. The coupling may be used for rotation in either direction, half of the rollers being under compression and the other half idlers.

Chief among the claims for this new coupling is the statement that true alignment and adjusting of the shafting is not quite so necessary with the L. R. Coupling. Even with an angular misalignment up to 7½ deg., lateral misalignment up to $\frac{1}{16}$ in., and end play up to $\frac{3}{4}$ in., the L. R. Coupling will function properly and with quiet efficiency.

Paint Spray Gun

THE Weil Lectrospray, a new electric spray painting device developing sufficient air pressure to spray any liquid finish, is being manufactured by the Weil Machine Company, of Detroit, Mich.



The Weil Lectrospray

One prominent feature of the new gun is the arrangement of the motor-compressor unit. It may be slung over the shoulder with the strap provided, or set on a bench or on the floor. According to the manufacturer, it effectively sprays any liquid finish of proper consistency, including lacquers, paints, bronzes, insecticides, disinfectants, and even whitewash and calcimine. This tool is operated by simply plugging into an electric light socket and snapping the switch. Adequate pressure is generated by the motor compressor to produce a uniform spray, the density of which is controlled by an adjustment of the nozzle.

When in use, only the paint container and the spray gun itself are held in the hand. The Weil Lectrospray is fully guaranteed, being manufactured only from the highest grade materials and finished in polished aluminum.

Blast Furnace Equipment

A COMPLETE line of blast furnace equipment designed for one-man operation has been developed by the Otis Elevator Company, 250 Eleventh Ave., New York, N. Y.

The man who operates the Larry car also initiates the skip bucket operation. From then on the charging operation of the furnace is automatic. Three machines are used as follows: Machine No. 1 is known as the blast furnace skip bucket hoisting machine, No. 2 is a combined small and large bell hoisting machine, and No. 3 machine is the automatic blast furnace stock line recorder.

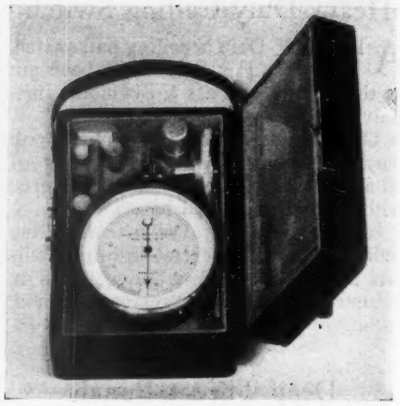
After a predetermined number of loads have been dumped on the large bell, a sequence switch actuated by the operation of the small bell initiates the operation of the large bell. After the large bell has been operated the automatic blast furnace stock line recorder operates and gages the amount of stock in the furnace. This gage is recorded on a 24-hour clock-driven chart visible to the Larry car operator. In addition a remote recorder giving a similar record is provided in the blast furnace supcrintendent's office.

Tachometer

A TACHOMETER of improved design, which, it is claimed, is the only instrument that may be used for showing acceleration speeds and other forms of speed variation, is now being introduced by Herman H. Sticht & Company, 17 Park Row, New York, N. Y.

This model has a centrifugal type measuring element which reads directly in r.p.m., and shows the values instantaneously.

The illustration shows a single-range instrument, but multi-range instruments are also available. Chief among the advantages claimed for the single-range type, are the following: It has no gears to shift or to be damaged due to carelessness, it is easier to read, it is impossible to read the wrong scale.



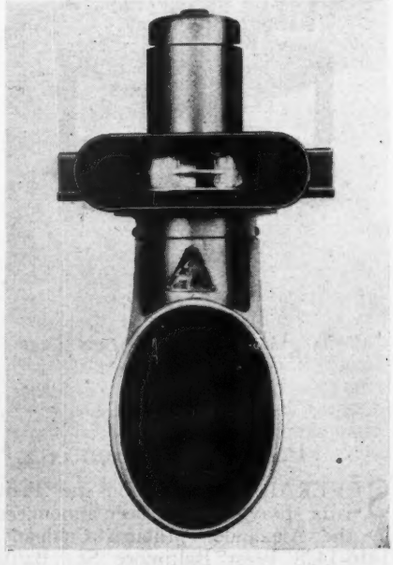
Herman H. Sticht & Company Single-Range Tachometer

Siren

A NEW motor vehicle siren, which will be known on the market under the trade name Luren, has been invented by Christian A. Volf, 366 Madison Ave., New York, N. Y.

The siren will be manufactured in three sizes for motor vehicle use, and for use with call and signal systems. It is featured with two separate horns and an entirely closed sounding box, the intake mouthpiece being approximately three times the size in sq.in. of the exhaust mouthpiece.

From that it will be clearly seen that the influx of air current through the intake horn is far greater than into the exhaust, and that the velocity of air current passing out through the exhaust mouthpiece, which is part of the sounding box, is more than double the velocity of the speeding vehicle.



Luren Motor Vehicle Siren

Wrench Set

ANOTHER new Williams - Husky Combination Wrench Set has been made possible by the recent reciprocal sales arrangement between J. H. Williams & Company, Buffalo, N. Y., and the Husky Wrench Company, Milwaukee, Wis. This arrangement enables each company to merchandise in combination sets the other's quality open-end, or socket wrenches. According to the manufacturers every "Superrench" and "Husky" socket is guaranteed against breakage.

The Williams-Husky Electrical Set No. 287 is claimed to be the only complete assortment on the market combining open-end and socket wrenches to service the electrical equipment of all makes of cars, for general electrical and radio work, and for all delicate adjustments. The set contains seven Williams Midget "Superrenches" (Chrome-Molybdenum steel), sizes $\frac{7}{32}$, $\frac{1}{4}$, $\frac{9}{32}$, $\frac{11}{32}$, $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}$ in., each wrench having two openings of the same size—but at different angles (15 deg. and 75 deg.).

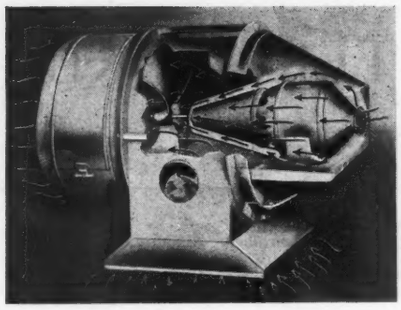
The Husky wrenches included in the set are 8 "Baby" sockets, tapered for work in close quarters, sizes $\frac{5}{32}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{11}{32}$, $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}$ in., together with a 5-in. combination Tee and a 4½-in. handy grip. The set is packed in a convenient and durable metal box, size 5¼x2⅜x1 in. high. The total weight is 1½ pounds.

Williams-Husky Combination Wrench Set

Ventilator Unit

AN EXPLOSION-PROOF ventilating unit for operation with air finishing booths has been announced by the Paasche Air Brush Company, 1909-27 Diversey Parkway, Chicago, Illinois.

According to its maker, the universal mounting and housing designed for this unit provides unusual convenience in erection and is adjustable for four mounting positions so that the outlet connection can be made in the most convenient place. The Westinghouse ventilating motor is fully enclosed and mounted on the top, outside of the path of the fumes, saving space and affording positive safety. The motor bearings are protected from the paint fumes by an air space between the bearings. Screened air pulled over the motor acts as a cooling agent and prevents any possible explosion. The announcement further states that this unit is equipped with a specially designed, three-blade aluminum fan which handles an unusually large volume of air per hp. It is possible to clean and remove this fan without disassembling the unit. The motor can be furnished in four sizes, ¼, ½, 1 and 2 hp., and in both a.c. and d.c. types.



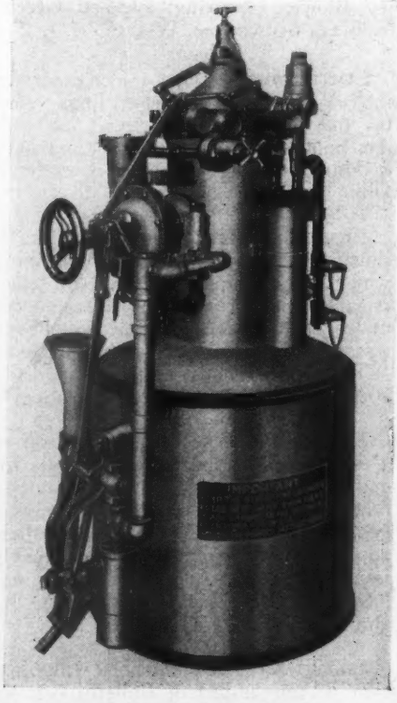
Paasche Air Company Ventilating Unit

Acetylene Generators

THREE medium pressure-type acetylene generators for welding and cutting have been placed on the market by the Oxweld Acetylene Company, 30 East 42nd Street, New York City. The type MP-2 medium pressure acetylene generator is built in two sizes, having 50 lb. and 100 lb. carbide capacity respectively, replaces the earlier model while the Type MP-3 has a 300-lb. carbide capacity and is entirely new, no pressure type generator of this size having been manufactured by this company before. These generators are suitable for supplying pressure type, or medium pressure welding and cutting blowpipes, it is stated.

The type MP-2 generator uses ¼ by $\frac{1}{12}$ in. carbide. The shipping weight in the 100 lb. size is 1,000 lb., and in the 50 lb. size, 925 lb.

The type MP-3 generator consists essentially of two sections, the lower being a cylindrical shell, the upper a shell in the shape of a truncated cone. The diameter of the shell is 42½ inches. Shipping weight is 2,300 lb.

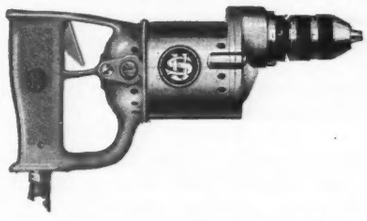


Oxweld Acetylene Company Acetylene Generator

High-Speed Electric Drill

TO MEET the growing demand for high-speed, lightweight, ¼-in. portable electric drills, the United States Electrical Tool Company, Cincinnati, Ohio, now has two in regular production.

One of these, known as the ¼-in. special direct drive drill, operates direct on the armature shaft at a speed of 10,000 r.p.m., and weighs only 4 lb. The other, known as the ¼-in. special gear reduction drill, operates at 2,000 r.p.m. and is one-eighth of a pound heavier.



United States Electrical Tool Company High-Speed ¼-In. Drill

According to the manufacturer, a new feature of these drills is their keyless chucks. Another is their easy accessibility in close places. Both drills embody a universal motor that operates on either a.c. or d.c. of 60 cycles or less, equipped with SKF ball bearings throughout, double silk insulated enameled armature wire, chrome nickel steel gears, one-piece frame and commutator head, and a trigger switch in the handle.

Flow Meter

A NEW type of indicating flow meter suitable for measuring the flow of air gas, saturated or superheated steam and of other liquids at any temperature, vacuum or pressure, has now been placed on the market by the Merriam Company, Cleveland, Ohio.

According to the announcement, the meters are designed primarily for high line pressure, 1,000 lb. per sq.in. but with slight modifications they may be used with equally satisfactory results on vacuum or on low pressure. In view of the very high pressure which must be dealt with in many cases, and to the inaccuracy which would be caused in the readings by even the smallest leakage, it was decided to weld all pipe lines, valves, etc., in the meter connections instead of using threaded unions. This was done by means of the new atomic hydrogen welding process.

TRADE LITERATURE

You Should Know About

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

TURBINES — Folder GEA-1011 describes GE turbines type F, 500 to 2,000 kw.—General Electric Company, Schenectady, N. Y.

MANIT SYSTEM—"The Manit System in Your Plant" is the title of a new 55-page brochure containing full information on the Haynes Manit system of wage payment. — Haynes Corporation, First National Bank Building, Chicago, Ill.

FLEXIBLE COUPLINGS—The new bulletin No. 180 describes the CS type developed particularly for close coupled application, and also the CH type added to the standard line for high-speed turbine work. —The Falk Corporation, Milwaukee, Wis.

LIGHTING — "Light and Production" is the title of a new 16-page booklet on industrial lighting, especially prepared for the industrial executive.—Benjamin Electric Manufacturing Company, 120 South Sangamon St., Chicago, Ill.

PULVERIZERS—Catalog No. 450 contains 32 pages describing the wide application of the swing hammer principle of reduction, and lists 54 basic materials all of which may be successfully reduced by the Jeffrey Swing Hammer Pulverizer.—The Jeffrey Manufacturing Company, Columbus, Ohio.

SYNCHRONOUS MOTORS — A copyrighted circular No. 501 entitled "Flywheel Effect Recommendation for Air Compressors Based on Ideal Synchronous Motor Drive," and illustrated with ideal installations, graphic curves, etc., has just been issued.—The Ideal Electric & Manufacturing Company, Mansfield, Ohio.

OIL CIRCUIT BREAKER—Circular No. 1799 describes the Type "0-241" oil circuit breaker.—Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

MEGOHMER—The "DM" model Megohmer, a combined Megohmmeter and voltmeter, with a self-contained d.c. generator, is described in bulletin No. 170.—Herman H. Sticht & Company, 15 Park Row, New York, N. Y.

LUBRICATION. — "Industrial Lubrication" describes the sixty different types and consistencies of Gredag lubricants and gives definite recommendations for their applications to industrial and automotive machinery of all kinds.—Acheson Graphite Corporation, Niagara Falls, N. Y.

CONTROLLERS — Publication No. 500 contains a description of a.c., drum controllers and accessories for general purpose slip-ring motors.—Union Electric Manufacturing Company, Milwaukee, Wis.

MOTORS—Bulletin No. 507 describes several of the many special types of L-A direct current motors built for particular purposes.—The Louis Allis Company, Milwaukee, Wis.

LANTERNS—A new 40-page booklet has recently been issued containing a complete description of the 22 types of N-L universal signal lanterns, together with lantern flasher control and reflector units for steel mills, factories, and highway use.—The Nichols-Lintern Company, 7960 Lorain Ave., Cleveland, Ohio.

BLOWERS — A new bulletin has been published entitled "Induced Draft," and describes exhaust fans as applied to the firing of locomotives and exhausting of gases from railroad roundhouses.—Bayley Blower Company, 732-750 Greenbush St., Milwaukee, Wis.

LIMIT STOPS—A new folder describes the Youngstown safety limit stop for use on cranes with both a.c. and d.c. motors.—The Electric Controller & Manufacturing Company, Cleveland, Ohio.

PUSHING JACKS — Bulletin No. 709 illustrates the Simplex jack for pushing water or gas pipes, or pipes for electrical service or for oil heating supply under paved streets or gardens or lawns irrespective of temperature conditions. —Templeton, Kenly & Company, Ltd., 1020 South Central Ave., Chicago, Ill.

SPEED REDUCERS—The description of a new series of speed-reducer units together with charts containing horsepower capacities, general data on Sykes gears and illustrations showing their application is contained in a newly issued booklet. — The Farrel-Birmingham Company, Inc., 344 Vulcan St., Buffalo, N. Y.

ILLUMINATION — "Airport Illumination" is the subject of Bulletin G.E.A.-982. Views of lighted airports are shown, and descriptions given of rotating beacons, boundary lights, floodlights, ceiling lights, wind cone lights, air marking signs and other associated devices. — General Electric Company, Schenectady, N. Y.

HEATERS—Publication H-4 called a "Dictionary of Uses" contains a list of proven uses of C-H electric space heaters from letters written by customers.—The Cutler-Hammer Manufacturing Company, Milwaukee, Wis.

GRAPHIC INSTRUMENTS — A four-page bulletin, No. 828 describes and illustrates the methods by which this company designs, manufactures and inspects their products.—Esterline Angus Company, Indianapolis, Ind.

WELDING—A bulletin describing the "Electronic Tornado" welding process in all its phases, including a treatise on the advantages of the use of the carbon electrode over the metallic electrode has recently been issued. — The Lincoln Electric Company, Coit Road and Kirby Ave., Cleveland, Ohio.

UNDERCUTTER — A small folder has been issued describing the new improved Ideal mica undercutters.—Ideal Commutator Dresser Company, Sycamore, Ill.

WATER HEATERS — There has been issued recently a bulletin containing complete information on the indirect method of heating water for large buildings.—Davis Engineering Corporation, 90 West St., New York, N. Y.

PORTABLE ELEVATORS—Bulletins 83-A and B describe the revolvable base, the inclosed gears and the splash system of lubrication, new Revolvator features. —Revolvator Company, 336-352 Garfield Ave., Jersey City, N. J.

TRAMRAIL SYSTEMS — "The Fundamental Principles of Materials Handling Applied to Paper Mills" is the title of a folder describing the function of the Cleveland Tramrail System in this industry.—Cleveland Crane & Engineering Company, Wickliffe, Ohio.

SWITCHES—Bulletin No. 21, covering its accessible fuse meter service and main entrance switches, is now being distributed by this company.—The Wadsworth Electric Manufacturing Company, Covington, Ky.

CENTRIFUGAL PUMPS—A 32-page illustrated bulletin, No. 273, contains a comprehensive treatment of the subject of high-pressure, multi-stage centrifugal pumps. — Byron-Jackson Pump Company, Berkeley, Calif.

RESISTANCE THERMOMETERS — The L.&N. line of resistance thermometers for controlling, recording, and indicating temperatures is described and illustrated in a recent 28-page catalog, No. 80.—Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.